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Journal

—OF THE—

American Ceramic Society

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries.

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JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 2 **June, 1919** **No. 6**

EDITORIALS.

THE FIFTH CHEMICAL EXPOSITION.

Those who were in attendance at the Fourth Chemical Exposition in New York last year will require little urging to take them to the Fifth Exposition to be held in the Coliseum and 1st Regiment Armory at Chicago, the week of Sept. 22nd. The Chemical Exposition has come to be one of the most important industrial events of the year. At the Exposition of last year were shown achievements of American industry in meeting war demands and in the development of sources of supply to replace foreign materials unavailable under existing conditions. At the Exposition of this year will be shown many of the advancements made since a year ago, in addition to some which have hitherto been undisclosed to the public.

The ceramic industry, although one of the oldest manufacturing industries, is at the same time one of the least known of the great technical industries. The representation of the American Ceramic Society at the past two Expositions has gone far towards bringing the importance of the industry to the attention of the public and related industries. Plans are well under way for a suitable representation of the Society at the Chicago Exposition and it is hoped that a goodly number of our members, particularly those in the West, will take advantage of this opportunity to get together and study the advances made in their own and related industries.

STANDARDS FOR MATERIALS.

We have repeatedly heard statements to the effect that American clays and other pottery materials are subject to undue varia-

tions in quality from one shipment to another or even in the same shipment. This is said to be particularly true of ball clays and kaolins. Although some improvement in quality has been noted it would appear that the exercise of greater care in the selection and preparation of clays for the market would lead to a better understanding between the clay producer and user. However, the clay users are partly responsible in many cases for the poor quality of clays which are delivered to their plants. Very often, little or no attention is paid to the condition and quality of the clay as it is delivered, and it is only when losses occur in manufacture that complaints are made as to the quality of the clays. The simple and obvious tests which should be applied to every shipment of clay received are too often neglected, or the tests applied are inadequate to a determination of the acceptability of the clay for the purposes used. Tests as to moisture content, shrinkage, fineness, color and cleanliness should be made upon each shipment of material received. We know of plants where no attention is paid to the moisture content of the clays and other materials which go into the body mixtures. A variation of 10 per cent in the moisture content of a clay is not unusual and unless this is taken into consideration in the preparation of the batch the proportions of the mixture will be thrown out and a uniform product will not result.

Once the consumer has established standards for his materials the producer will very quickly endeavor to meet those standards. As it is now, the producer is not to be greatly blamed for the quality of his product. In many cases most anything will be accepted without question—in fact, he does not know just what is required of his materials and just what are the allowable variations in any one particular. The adherence to rigid specifications for the raw materials is obviously the first step in the standardization and improvement in quality of our ceramic wares.

CERAMIC ABSTRACTS.

Starting with this number, abstracts of ceramic literature will be published monthly in the Journal. Ceramic literature is so widely diversified and scattered that considerable difficulty

has been experienced in the classification and assigning of the work so as to thoroughly cover the field. Once a full corps of abstractors has been secured it is planned to cover the entire field of literature on all ceramic subjects, including clays and related products, glass, cement, lime and ceramic patents. The articles will be abstracted quite fully and in such a way as to render them easily readable by most of our members.

THE SUMMER MEETING.

Attention is called to the announcement of the Summer Meeting on page 503 of this number. Owing to a change in plans the meeting will convene on Monday morning, August 4th at the Hotel Iroquois, Buffalo, instead of Monday evening at the Hotel Statler, as announced in the May number of the Journal. An inspection trip for Monday afternoon is being arranged. Monday evening will be reserved for Professional Division meetings and a general business meeting of the Society. Tuesday is reserved for a trip to Niagara Falls and on Wednesday, at least three industrial plants will be visited in Buffalo. Wednesday evening the party will take the nine o'clock boat for Cleveland where the remaining sessions will be held.

ORIGINAL PAPERS AND DISCUSSIONS

PROCEDURES IN THE MANUFACTURE OF OPTICAL GLASS.

By W. S. Williams and C. C. Rand.[1]

Introduction.—The Bureau of Standards began experimental work on the production of optical glass in July 1914, and investigations along this line are still in progress. The present paper is intended as a brief statement of the general problem of making optical glass. A more thorough discussion of the processes involved and of the results obtained will be given in a later paper or bulletin.

Requirements for Optical Glass.—Optical glass is that type which is of a quality suitable for use in precision instruments such as range finders, gun sights, telescopes, binoculars, periscopes and camera lenses. The requirements for these purposes are very exacting. The most serious defect is inhomogeneity. This may be manifested as differences in the refractive index in different parts of the melt, or by streaks or thin sheets of different index from the surrounding glass. The latter condition is by far the most troublesome.

By the use of suitable apparatus, irregular deviations of light rays which are caused by defects variously known as "striae," "veins," "cords," "waves," etc., may be detected. These may occur in threads or sheets, or in wide diffuse bands either straight or curved and sometimes looped and twisted. The most powerful and delicate precision instruments are made with glass entirely free of striae and practically free of stones. For certain instruments, however, a few small striae or seed are permitted

[1] By permission of the Director, Bureau of Standards.

as their presence will cause no appreciable harm. In the final annealing all strain must be eliminated. Devitrification, cloudiness or crystallization will cause the rejection of the glass. Hygroscopic or tarnishable glass cannot be used in instruments which are to be exposed to weathering conditions. Furthermore, the product must have sufficient strength to prevent breaking in the grinding, polishing and mounting operations.

The raw materials and the melting pots must be free from such impurities and elements as will color the glass and thus increase the absorption of light. However, other characteristics are at times so desirable that light absorption becomes a secondary consideration, as in special flints and dense barium crowns. Compositions and melting operations should be coördinated and standardized to produce, in successive melts of the same composition, glasses which are as constant as possible in optical properties, such as the refractive index, dispersion and density. It is largely upon these values that the optician makes his choice and calculates his lens elements accordingly. It even becomes necessary in some optics to recompute formulas for slight changes in these values between different melts, and even to reconstruct grinding and polishing tools.

Production of Optical Glass.—The exacting requirements, the small market for the product, and the prejudice in favor of imported glass, have been the causes of the small production of optical glass in the United States. A great deal of research was necessary before production could be assured. Manufacturers were reluctant to spend money on research without any assured profit, and in this case there was no promise of large returns. In spite of these unfavorable factors, several glass manufacturers are reported to have attempted quantity production of optical glass in America. About 30 years ago an attempt was made at Lenox, Mass., but it was abandoned. About the time of the Spanish-American war some very good optical glass was made in the Macbeth factories at Elwood, Ind. In 1912, the Bausch & Lomb Optical Company built an experimental plant at Rochester, N. Y., and with the aid of an experienced man began production.

With the beginning of the war in 1914 came a great demand for instruments, glass stocks were quickly depleted and America realized the folly of depending on Europe for its optical glass. Since practically all naval and military operations depend on accurate optical instruments, it was imperative to take such measures as would secure an ample supply to meet the great and rapidly increasing demand. In 1914 the Bureau of Standards began experimental work on the production of optical glass. When the United States entered the war a number of manufacturers began the production of optical glass, some of them on quite a large scale. Among these were: The Pittsburgh Plate Glass Co., The Keuffel and Esser Co., The Hazel-Atlas Glass Co., The Spencer Lens Co., The Carr-Lowry Glass Co., and the H. C. Fry Glass Co.

Many errors and failures were naturally to be expected during the experimental stages of development. The ground work was based on the chemical analyses of European glass and a meager knowledge of European technique.

Raw Materials.—One of the first problems to be solved was that of securing pure raw materials. The very nature of the product demands a degree of purity unknown in other lines of glass manufacture. Propagandists had been very active in attempting to convince America that optical glass was a product altogether too difficult to be attempted here. Well known glass sands were found to contain enough iron to condemn them for optical glass, where freedom from color is a requirement, and no decolorizers such as manganese and selenium can be used. Sands were found, however, which were sufficiently pure and furthermore had the requisite size and uniformity of grain. The sands used were readily available and obtainable at a fair price. With the exception of the removal of magnetic iron, they were used just as received from the shippers without refinement or further treatment. This also holds true for all other materials used in manufacturing optical glass at the Bureau of Standards. Typical screen tests of sand used are reported in Table 1. The maximum and minimum percentages of impurities found in the materials used are given in Table 2. The color and transmissions

obtained with these materials, melted in a porcelain pot, compare very favorably with those published in the price lists of the foreign makers.

TABLE 1.—TYPICAL SCREEN TESTS OF SAND.

Screen size.	Per cent remaining on screen.
35	2.47
65	82.59
100	8.76
150	3.90
200	1.77
Through 200	0.43

TABLE 2.—IMPURITIES FOUND IN MATERIALS

	Fe_2O_3.		SO_3.		Cl.	
	Max.	Min.	Max.	Min.	Max.	Min.
Barium carbonate.....	0.009	0.0005	0.12	0.0774	0.13	0.01
Barium carbonate, C. P.....	0.0067	0.004	0.08	0.018	0.069	0.0124
Red lead.....	0.0056	0.0015	0.055	0.01	0.13	0.017
Soda ash.....	0.003	0.0014	0.03	0.0049	....	....
Hydrated lime.....	0.048	0.026	0.167	0.06	....	....
Potash (K_2CO_3).....	0.01	0.004	0.07	0.018	0.31	0.11
Zinc oxide.....	0.006	0.0057	0.327	0.11	0.35	0.078
Saltpeter (KNO_3)....	0.0019	0.0007	0.0016	....	0.07	0.05
Borax.....	0.002	0.0004	0.034	0.018	0.005	0.0034
Alumina (Al_2O_3).....	0.0022	0.0022	0.15	0.15	....	....
Sand.....	0.02	0.0148	....	....	....	....

The intimate mixing of the ingredients of the batch is very important. One of the theories advanced for the formation of striae is that the striae are of different chemical composition from the surrounding glass. Viewed in this light, it is obvious that the tendency toward striae is lessened by intimately mixing the batch. At the Bureau of Standards the batch materials are passed through a 12-mesh screen and then mixed for one hour in a ball mill using no pebbles.

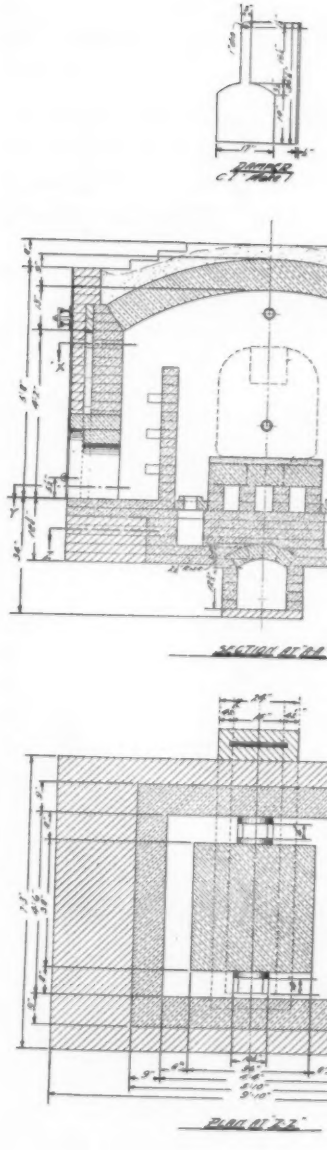
Pots for Optical Glass Melting.—When large-scale production of optical glass was commenced a most serious obstacle was encountered by the failure of pots. Pots from many commercial sources were tried but the action of the glass upon them was so corrosive that it ate its way through the walls in a short time. The successful solving of this problem at the Bureau of Standards has been fully described in this Journal.[1] A covered pot was adopted because it prevents contamination from particles of the furnace crown. The glass is melted in single-pot furnaces fired by natural gas and compressed air. The greater part of the waste gases are removed through flues in the floor leading to a stack flue. In Fig. 1 are shown a part of the working drawings of this furnace.

Before drying, the inside walls of the pot should be carefully finished and the grog particles worked well back from the surface and covered with clay. This clay coating offers a resistant shield between the glass and the pot body. When the pot is too dry before finishing, the grog will not readily work back and the pot-maker is then compelled to wet the surface excessively. Fine, hair-line, surface cracks result and these may escape detection before the pot is used. The glass gains access to the pot body through these cracks causing pieces of the pot to become loosened and form "stones."

Many pot failures have been due to an attempt to use the pots before they were thoroughly dried. Still others are due to an unequal distribution of heat causing the pots to warp and crack. The drying schedule used is shown in Fig. 2 and the burning schedule in Fig. 3. It has been found that a pot may be burned so dense as to become too brittle for use. When these pots are chilled they fall apart and the melt is lost.

The practice at the Bureau of Standards' factory is to set the pot in a melting furnace on a bed of sand about three inches deep. A brick is placed under the front of the pot to permit circulation of heat thus insuring a well-burned bottom. When the furnace has reached 1100° C (Fig. 3) the brick is removed and the pot lowered into the sand bed. After the pot is vitrified

[1] A. V. Bleininger, *J. Am. Ceram. Soc.*, 1, 1–23 (1918).



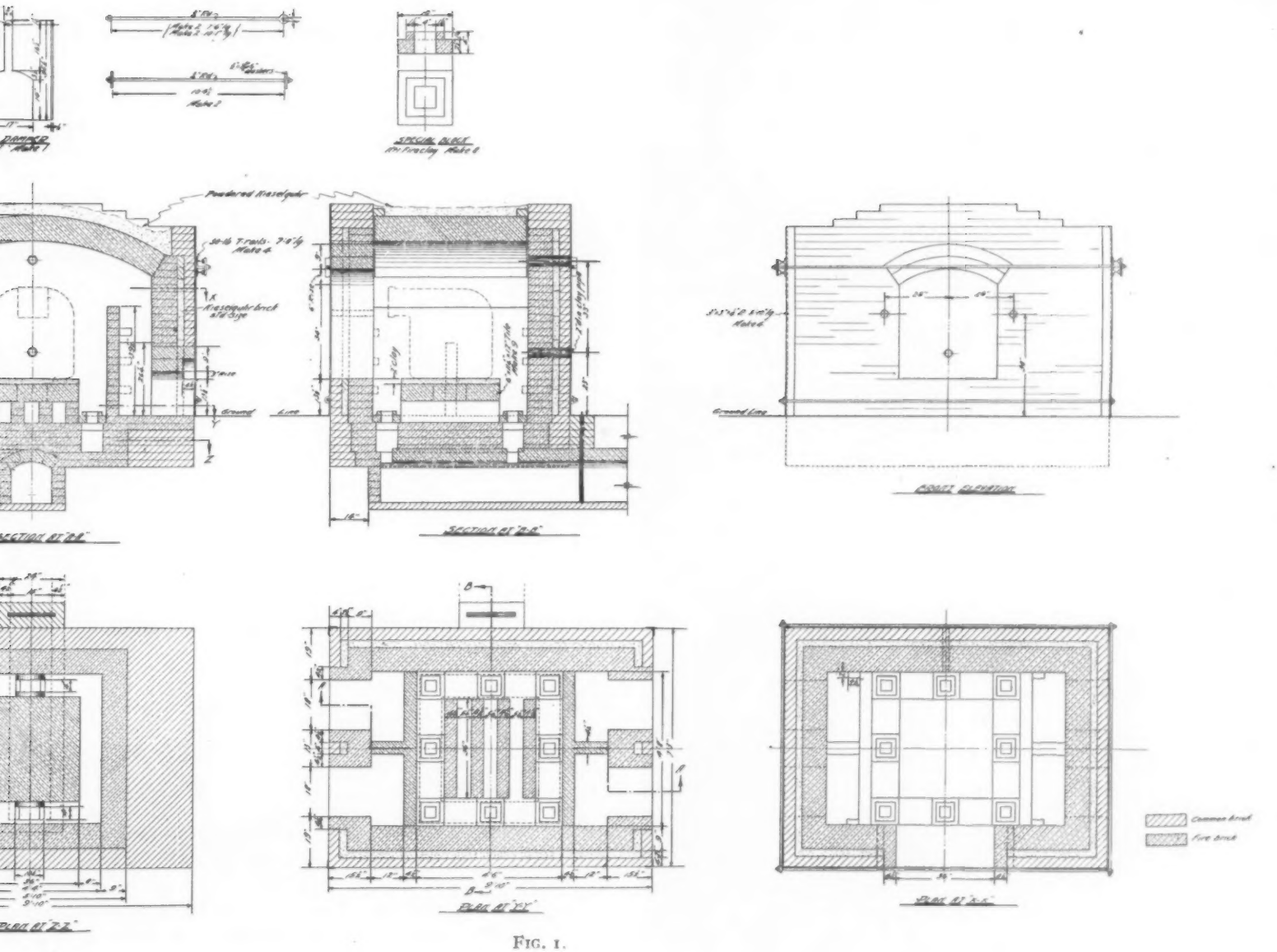


FIG. 1.

the temperature is reduced, if necessary, to the melting schedule as shown in Fig. 4.

Charging the Batch.—When the melting schedule is reached 200 pounds of cullet are put into the pot. This forms a coating of glass over the bottom of the pot and protects it from the active corrosion of the raw batch. The cullet is carefully selected and

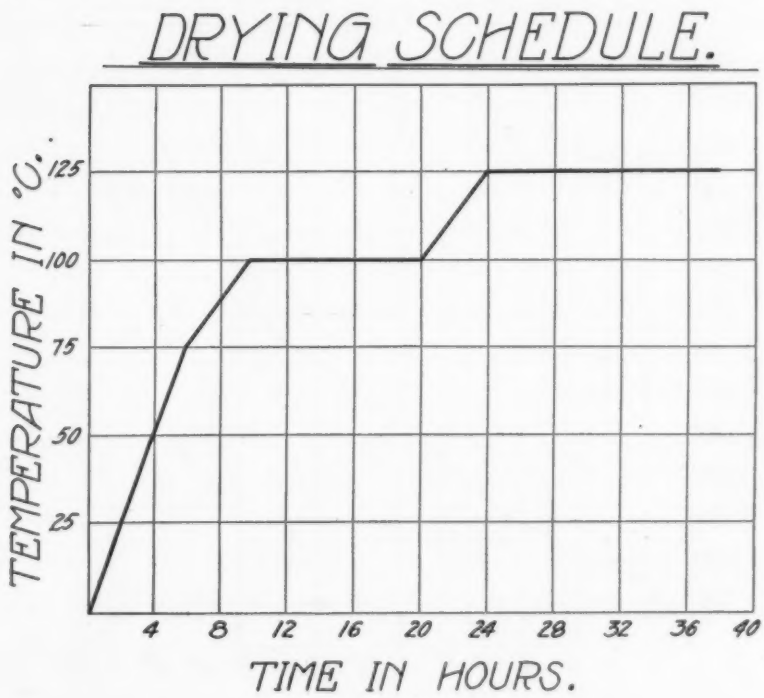


FIG. 2.

inspected for color, stones, pot-shell, sand and dirt. It is broken to nut-size and washed. When cullet is used with the raw batch it is mixed uniformly with it.

One hour after the cullet is introduced a fill of 150 to 200 lbs. of batch is made. The same amount is filled every $1\frac{1}{2}$ hours thereafter until the pot is full. During filling and fining it is important to avoid a big drop in temperature; for if the glass is chilled,

it is very difficult to eliminate the fine seeds thereafter. "Seedy" glass at this stage of the melt may also result from a lack of readily volatile ingredients in the batch. The elimination of seeds in certain types of glass was accomplished by substituting nitrates for carbonates in the batch. Seeds may also be eliminated by

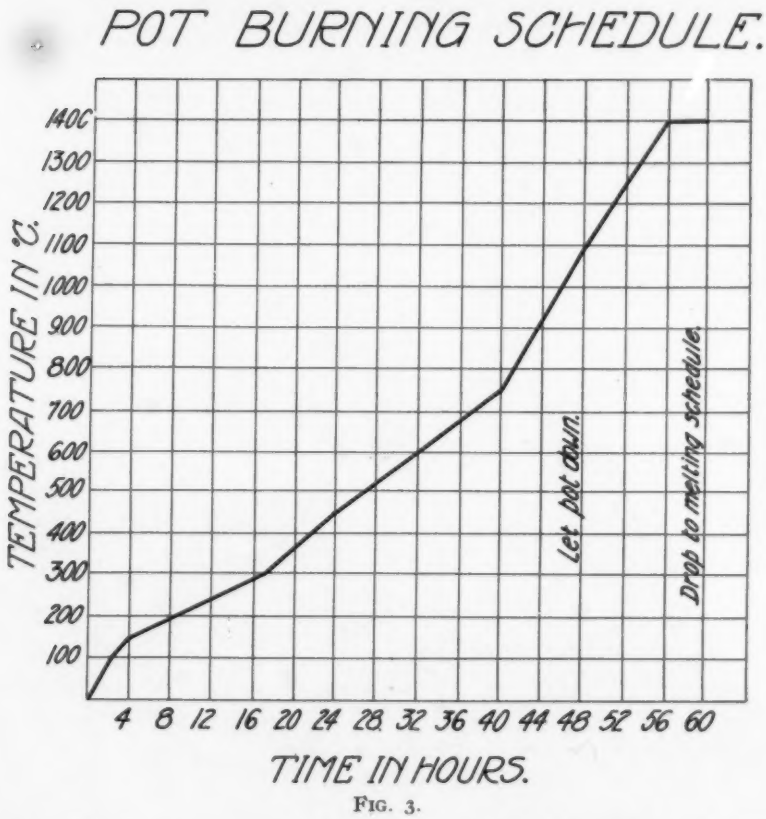


FIG. 3.

"blocking" with ammonium nitrate, which causes the metal to boil very vigorously. "Blocking" is done by wrapping about $^1/_4$ of a pound of ammonium nitrate in paper, placing the package in a forked rod and then plunging it into the center of the metal. Violent boiling ensues, and the operator must be on guard not to become burned.

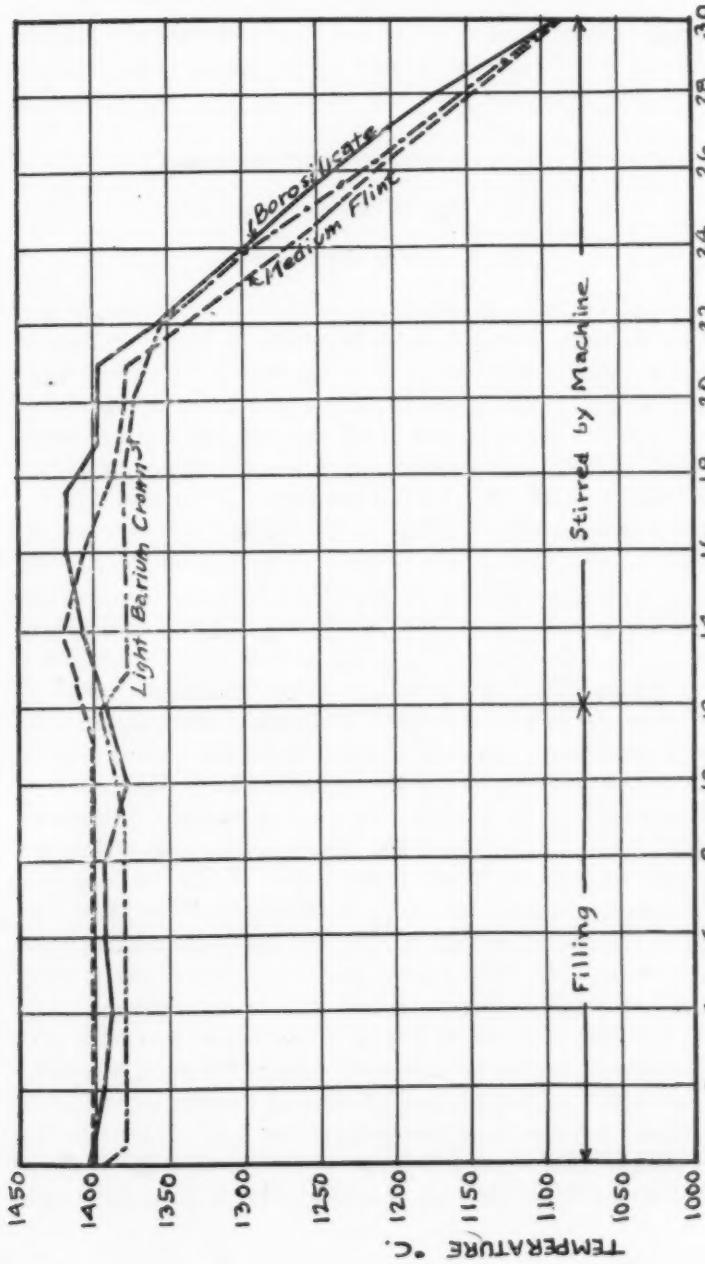


FIG. 4.—Typical time—temperature curves.

Stirring.—Two hours after the last fill a porcelain-clay stirring rod thimble is laid on the surface of the glass. This thimble, shown in Fig. 5, is cast from the porcelain pot mixture used in

FIG. 5—Stirring-rod thimble.

casting melting pots. It is heated to 1200° C and then allowed to attain the same temperature as the metal by laying on the surface of the glass for one hour prior to turning the closed end down into the metal. When in the latter position a water cooled iron rod is inserted in the open end of the thimble and stirring begins.

Typical melting and stirring schedules are shown in Fig. 4. As previously stated, the greatest percentage of rejected glass is due to inhomogeneity, or striae. This defect is overcome by stirring the metal until a homogeneous mixture is obtained. The refractive indices demanded in optical glass require compositions of materials whose densities vary widely. The heavier constituents have a tendency to segregate and settle to the bottom of the pot during filling and melting. These constituents must be stirred with the lighter ones until thoroughly incorporated with them. Furthermore, the glass adjacent to the pot walls is of a different composition from that of the center, which is due to the solvent action of the glass upon the clay walls of the pot. If this contaminated glass is stirred into the center of the melt and is not thoroughly assimilated, it will cause striae. While rotating, the stirring thimble is kept about three inches from the sides and bottom of the pot to prevent stirring the pot-contaminated glass into the center. As stirring progresses the radius of the stirring circle is continually shortened and the speed reduced. The stirring machine is shown in Fig. 6. Mechanical stirring is preferred because it insures the agitation of the entire melt, speed and radius are easily controlled, and the stirring thimble is kept away the required distance from the walls of the pot. When stirring begins, the machine is run at from 20 to 23 r. p. m. This speed is gradually reduced as the glass cools and stiffens, to prevent stir-

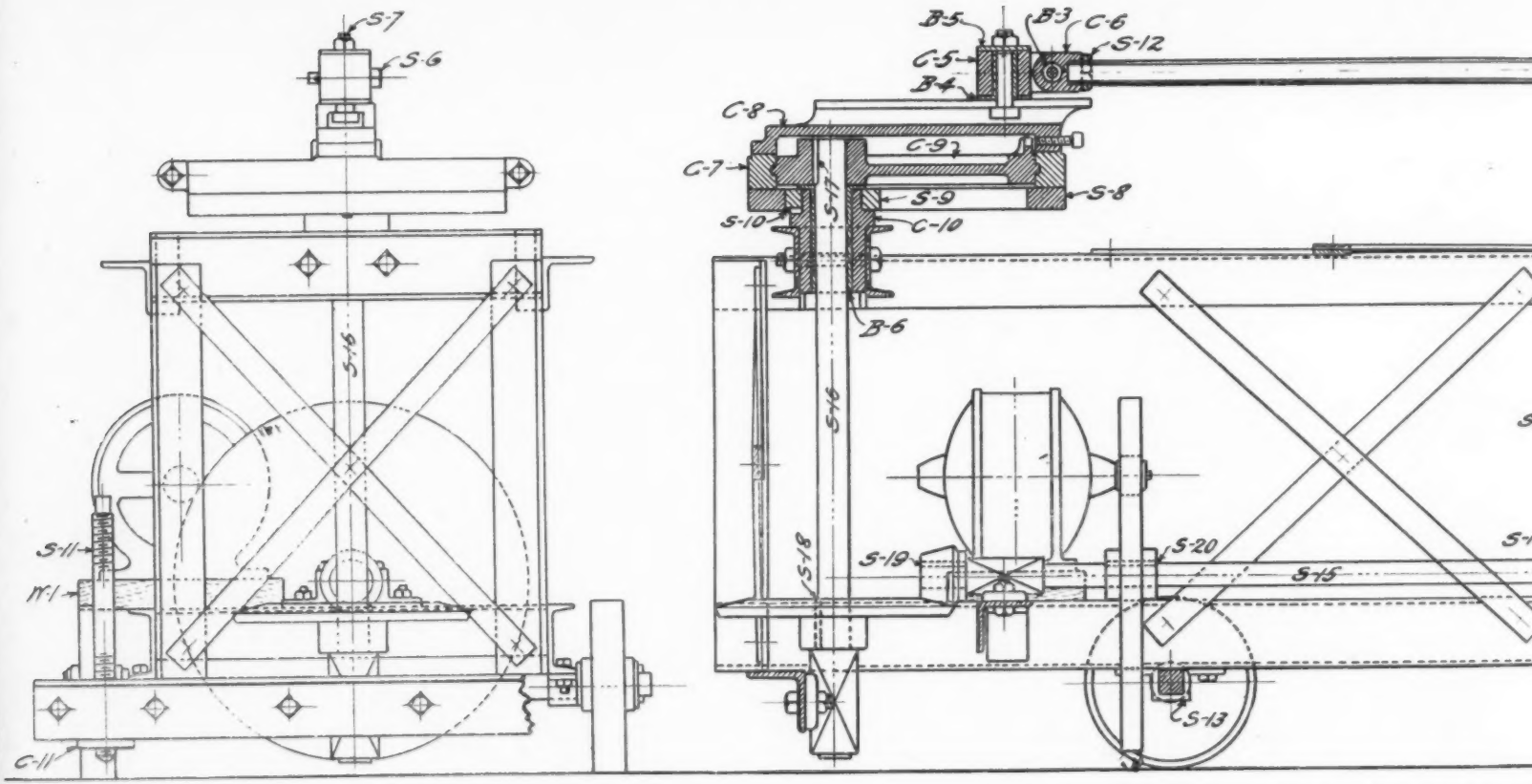
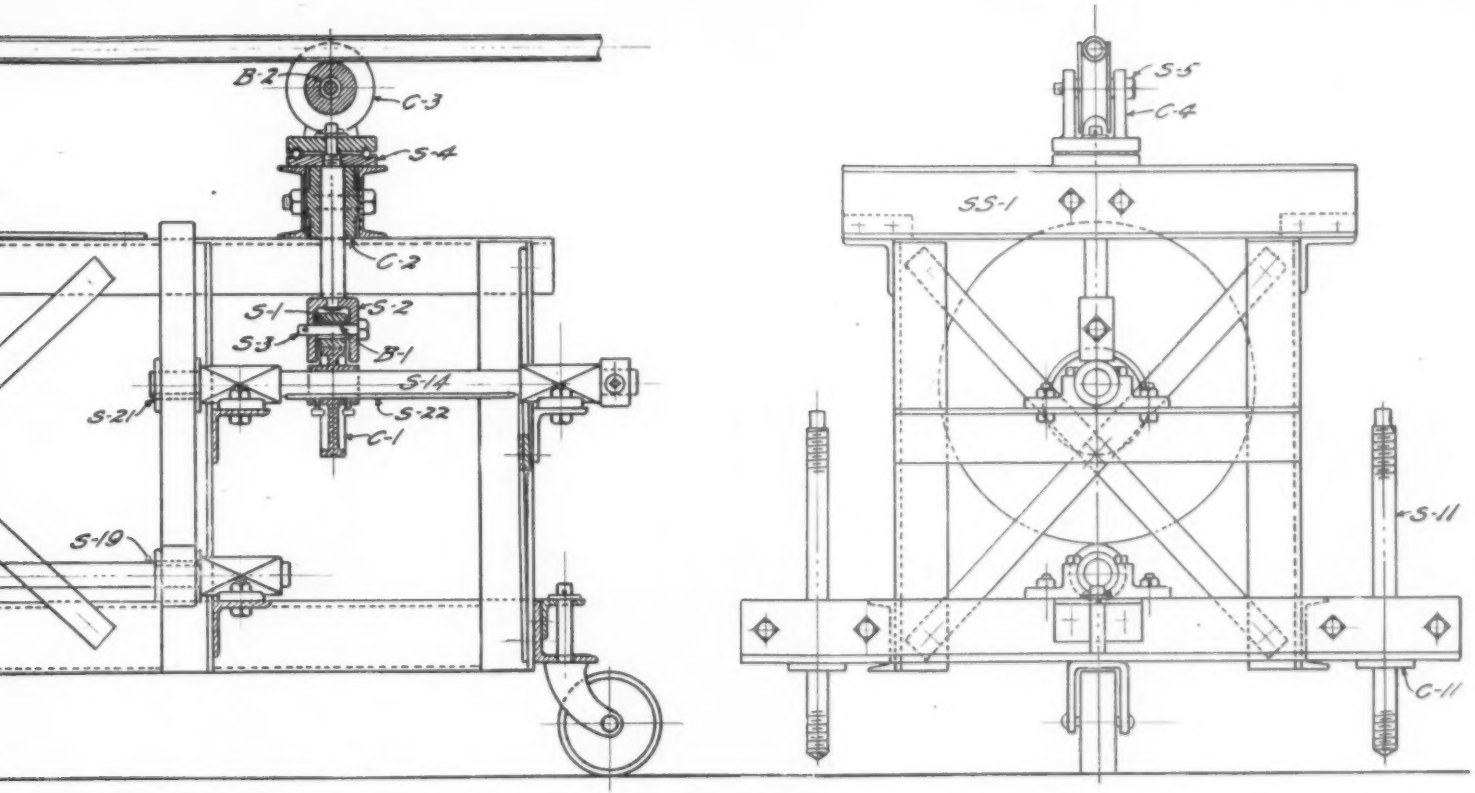


FIG. 6.—Glass stirring mac



irring machine.

ring air into the melt and causing big bubbles. When the temperature of the glass has been reduced to the proper point, stirring ceases and the thimble is removed. To prevent striae from reforming, the metal is cooled as quickly as possible from this point to about 700° C. This is done by tipping the pot back, placing a fire brick support under it, and directing a stream of compressed air against the bottom for 3 hours. When the pot is cool enough to handle, it is removed from the furnace and the clay broken from the glass. The latter is then given a preliminary inspection and broken to suitable sizes for molding.

Molding and Annealing.—A great deal of good optical glass was ruined during molding and annealing. Several methods of molding were tried. In all methods the glass was gradually heated to the softening temperature in a furnace. The treatment following this in one method was to place the glass in clay trays which were coated with a mineral powder to prevent the glass from sticking to the tray. The tray was placed in a furnace sufficiently hot to melt the glass until it flowed. It was then turned out of the tray and pressed. Another method followed was to place the heated piece in a small furnace, the floor of which was covered with the mineral powder. As the glass softened it was paddled by hand into a block which would fit into the iron mold of a press. Several powders were tried in the above methods, such as alumina, flint, mica, kaolin, lime, etc. The latter method is known to be the most satisfactory of all from the standpoint of economy and quality, but on account of lack of skilled workmen, could not be used. It was found necessary to resort to the following method: The glass was "stuck up" on a punty and softened in a glory hole, shaped at a bench by paddling, and then sheared into a mold and pressed. Small lenses and prisms do not require shaping. After pressing, the glass is annealed according to schedules which depend upon the kind of glass. For all kinds the heating schedule was the same for the first 12 hours. The temperature was brought to 200° C the first 4 hours, to 300° in 8 hours, and to 400° at the twelfth hour. During the next $3^1/_2$ hours the final temperature was reached, depending upon the kind of glass, as follows: flint, 480°; light crown, 520°; boro-

silicate, 550°; light barium crown, 610°; dense barium crown, 625°. The experimental work necessary in the determination of these temperatures was done by Dr. A. Q. Tool, of the Bureau of Standards. After reaching the maximum temperature, the glass was cooled at the rate of 5° per hour. No doubt all optical glass makers have endeavored to gather the glass directly from the pot and press it into lenses and prisms. This method would obviate the breaking of the pot and it could be used for several successive melts. The great waste of labor and glass incidental to breaking the glass to size and molding it would be eliminated, and a very substantial saving in fuel would be effected. In order to stir while gathering, the stirring rod is operated from the rear of the furnace, while the gathering is done from the front. The gatherer endeavors to follow directly in the path of the rod which insures the gathering of the most homogeneous glass. This work was carried on under the direction of Capt. H. C. Fry, Jr., who gave it considerable time and attention. The experiment was only partially successful, due to the gatherers not being accustomed to working with optical glass. Further experiments in gathering are contemplated and are thought necessary to conclusively demonstrate the success of the method as applied to commercial production. Decisive results could be obtained only by a comparison of several months' production by gathering compared with the old method.

Chemical Composition.—The compositions of the glasses made at the Bureau of Standards were developed to meet the demands of the military forces. Most of the types of glasses were based on analyses of glasses manufactured in Europe. Of course, some difficulty was experienced in converting the analytical results into a raw batch which would yield a glass of the desired optical constants. Experience demonstrated that the optical constants obtained by varying the chemical formula did not agree with the predicted result. It is true that occasionally the final result was close to the theoretical prediction, but in many cases it was wide of the mark. The optical properties do not depend entirely upon chemical composition. Other factors controlling them are temperature, time of melting, pressures, etc. Theoretically, the optical constants should not vary from melt to melt, pro-

viding all conditions are equal. In large scale production, however, the optical constants are not always the same for like compositions. This is illustrated in Table 3. From this table it is apparent that the optical results obtainable from a particular composition cannot be accurately judged from one melt. In fact, the indices will occasionally vary in the third decimal place in samples taken from different parts of the same melt.

TABLE 3.—VARIATION OF INDICES WITH SAME COMPOSITION AND OTHER CONDITIONS APPARENTLY EQUAL.

		N_D.	ν.
		1.6282	36.7
		1.6283	36.7
SiO_2	44.4	1.6268	36.7
PbO	46.0	1.6278	36.8
K_2O	4.1	1.6288	36.5
Na_2O	3.5	1.6248	36.6
CaO	2.0	1.6242	37.2
As_2O_3	0.4	1.6221	37.4
		1.6285	36.6
		1.6265	36.7

The effect of change in composition on index and dispersion is shown in Table 4. The indices herein presented are the averages of the indicated number of melts.

TABLE 4.—VARYING INDICES WITH COMPOSITION.

Designation.	Melts averaged.	SiO_2.	K_2O.	Na_2O	CaO.	ZnO.	B_2O_3.	PbO.	BaO.	As_2O_3.	N_D.	ν.
B-4..	10	44.4	5.0	3.5	3.0			44.0		0.2	1.62446	37.2
B-8..	10	45.6	4.1	3.5	3.0			44.0		0.2	1.62741	36.9
B-13.	10	44.4	4.1	3.5	2.0			46.0		0.4	1.62658	36.8
E-1..	7	48.1	7.5	1.0		10.1	4.5		28.3	0.4	1.56907	57.3
E-2..	7	48.0	6.1	2.0		10.0	4.0		29.5	1.4	1.57343	56.7
E-3..	7	47.6	6.0	2.0		9.8	4.0		30.5	1.5	1.57700	56.5
E-4..	5	46.0	6.1	2.0		10.5	5.5		29.5	1.5	1.57990	56.7

It should be noted that all the compositions given in this paper are the theoretical compositions used as a basis for making up the

TABLE 5.—MEDIUM FLINT.

Melt No.	Batch No.	% SiO_2.	% PbO.	% K_2O.	% Na_2O.	% CaO.	% B_2O_3.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	ν.	Transmission T.	Melting time.	Type of pot.	Per cent of cullet used.
21	B-1	44.1	44.7	9.8	1.2			0.2	1.60683	1.60222	1.61837	1.62808	37.5		57	Covered	20
54	B-2	44.4	44.9	6.1	1.2	3.2		0.2	1.62229	1.61751	1.63424	1.64438	37.2	98.3	52	Open	10
58	B-3	41.8	45.3	6.16	1.21	3.23	2.01		1.62890	1.62411	1.64095	1.65121	37.3	98.4	52	Open	10
75	B-4	44.4	44.0	5.0	3.5	3.0		0.2	1.62082	1.61762	1.63435	1.64447	37.2	99.1	49	Open	10
82	B-4	44.4	44.0	5.0	3.5	3.0		0.2	1.62241	1.61605	1.63267	1.64276	37.3	98.4	50	Open	0
89	B-4	44.4	44.0	5.0	3.5	3.0		0.2	1.62031	1.61559	1.63211	1.64216	37.5		51	Open	0
95	B-4	44.4	44.0	5.0	3.5	3.0		0.2	1.62441	1.61958	1.63648	1.64679	37.6	98.1	54	Open	0
99	B-4A	44.4	44.0	5.0	3.5	3.0		0.2	1.62659	1.62175	1.63872	1.64903	36.9	98.0	54	Open	10
100	B-4A	44.4	44.0	5.0	3.5	3.0		0.2	1.62683	1.62201	1.63905	1.64937	36.8	98.2	52	Open	10
109	B-4A	44.4	44.0	5.0	3.5	3.0		0.2	1.62781	1.62291	1.63997	1.65035	36.8	98.2	52	Open	10
110	B-4A	44.4	44.0	5.0	3.5	3.0		0.2	1.62495	1.62013	1.63701	1.64747	37.4	97.6	52	Open	10
111	B-4A	44.4	44.0	5.0	3.5	3.0		0.2	1.62528	1.62047	1.63728	1.64755	37.2	98.0	52	Open	10
112	B-4A	44.4	44.0	5.0	3.5	3.0		0.2	1.62518	1.62034	1.63723	1.64749	37.0	97.5	52	Open	10
128	B-5	44.5	42.0	7.0	3.5	3.0		0.2	1.60899	1.60450	1.62014	1.62959	38.9		49	Open	10
130	B-5A	44.5	42.0	7.0	3.5	3.0		0.2	1.59694	1.59270	1.60747	1.61636	38.4	98.5	49	Open	10
141	B-6	46.5	42.0	5.0	3.5	3.0		2.0	1.61811	1.6132	1.6294	1.63693	38.0	97.9	54	Open	10
142	B-7	45.6	43.2	4.9	3.43	2.95		0.2	1.62841	1.62365	1.64073	1.65115	26.8	98.7	54	Open	10
143	B-7	45.6	43.2	4.9	3.43	2.95		0.2	1.62426	1.61947	1.63626		37.2	98.2	55	Open	10
144	B-8	45.6	44.0	4.1	3.43	2.95		0.2	1.62546	1.62064	1.63753	1.64774	37.0	98.3	52	Open	10
158	B-8	45.6	44.0	4.1	3.43	2.95		0.2	1.62769	1.6227	1.6397		36.9	98.6	55	Open	25
160	B-8	45.6	44 0	4.1	3.43	2.95		0.2	1.6248	1.6200	1.6367		37.3	98.9	56	Open	25
161	B-8	45.6	44.0	4.1	3.43	2.95		0.2	1.6283	1.6234	1.6405		37.1	97.2	57	Open	10
162	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.62684	1.62202	1.63892		37.1	98.3	55	Open	25
163	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.6272	1.6223	1.6393		37.1	98.3	56	Open	25
164	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.6283	1.6236	1.6408		46.8	97.9	58	Open	25
165	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.62655	1.6216	1.6588		36.3	98.6	58	Open	25
166	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.63117	1.6263	1.6435		36.5	97.8	56	Open	25
167	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.6277	1.6229	1.6398		37.1	98.3	56	Open	25
168	B-8*a*	45.6	44.0	4.1	3.43	2.95		0.2	1.6250	1.6202	1.6369		37.4	98.3	56	Open	25
176	B-9	44.16	47.50	7.70			0.52	0.2	1.6243	1.6195	1.6366		36.4	98.5	56	Open	10

TABLE 5.—MEDIUM FLINT (*Continued*).

182	B-10	44.16	47.50	5.70	2.0		0.52	0.2	1.6237	1.6188	1.6360		36.3	98.7	53	Open	10
185	B-10	44.16	47.50	5.70	2.0		0.52	0.2	1.6222	1.6173	1.6344		36.4	98.9	49	Open	10
192	B-11	46.6	44.0	4.1	3.5	1.8	0.52	0.2	1.6141	1.6095	1.6257		37.9	98.1	55	Open	10
193	B-11	46.6	44.0	4.1	3.5	1.8	0.52	0.2	1.6203	1.6156	1.6321		37.5	98.1	55	Open	0
194	B-11*a*	46.6	44.0	4.1	3.5	1.8	0.52	0.2	1.6162	1.6118	1.6281		37.8		55	Open	10
209	B-12	45.6	45.0	4.1	3.5	1.8		0.4	1.6192	1.6145	1.6311		37.2	98.5	56	Open	10
211	B-12	45.6	45.0	4.1	3.5	1.8		0.4	1.6242	1.6194	1.6363		37.0	98.6	52	Open	20
214	B-13	44.4	46.0	4.1	3.5	2.0		0.4	1.6243	1.6194	1.6364		36.8		52	Open	25
215	B-13*a*	44.4	46.0	4.1	3.5	2.0		0.4	1.6274	1.6225	1.6397		36.4		50	Open	20
219	B-13*a*	44.4	46.0	4.1	3.5	2.0		0.4	1.6273	1.6224	1.6397		36.2		54	Open	30
220	B-13*a*	44.4	46.0	4.1	3.5	2.0		0.4	1.6315	1.6266	1.6441		36.2		55	Open	30
226	B-13*b*	44.4	46.0	4.1	3.5	2.0		0.4	1.6268	1.6219	1.6391		36.5	97.5	48	Open	50
254	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6165	1.6119	1.6282		37.7		30	Open	40
255	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6215	1.6167	1.6333		37.3	98.4	33	Open	40
256	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6341	1.6291	1.6469		35.8	98.9	34	Covered	0
258	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6282	1.6235	1.6407		36.7	98.6	30	Covered	40
259	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6283	1.6234	1.6406		36.7	98.4	32	Open	40
260	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6268	1.6219	1.6390		36.7	98.5	32	Open	40
262	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6278	1.6228	1.6399		36.8	98.3	32	Open	40
263	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6288	1.6239	1.6411		36.5		32	Open	40
265	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6248	1.6198	1.6369		36.6	98.4	33	Open	45
266	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6242	1.6194	1.6362		37.2	98.9	32	Open	40
267	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6221	1.6174	1.6340		37.4	98.6	32	Open	40
268	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6285	1.6236	1.6408		36.6	98.1	34	Open	40
269	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6263	1.6215	1.6385		36.7	98.5	32	Open	40
270	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6272	1.6224	1.6394		36.9	98.3	31	Open	40
271	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6266	1.6217	1.6388		36.6	98.5	30	Open	40
272	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6231	1.6181	1.6350		36.8	98.9	31	Open	40
275	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6300	1.6250	1.6423		36.8	98.7	33	Covered	40
276	B-13*c*	44.4	46.0	4.1	3.5	2.0		0.4	1.6242	1.6194	1.6363		37.0	98.6	31	Open	40
277	B-15	44.9	45.5	4.1	3.5	2.0		0.4	1.6233	1.6233	1.6185		36.7	98.4	33	Open	40
280	B-16	45.4	45.0	4.1	3.5	2.0		0.4	1.6193	1.6146	1.6312		37.2	99.1	31	Open	40
285	B-16	45.4	45.0	4.1	3.5	2.0	BaO	0.4	1.6211	1.6163	1.6330		37.1	98.4	31	Open	40
287	B-17	46.4	44.0	4.1	3.5	2.0	1.0	0.4	1.6218	1.6170	1.6338		37.0	98.5	30	Open	40
288	B-17	46.4	44.0	4.1	3.5	2.0	1.0	0.4	1.6173	1.6126	1.6291		37.3	98.5	31	Open	40
289	B-17	46.4	44.0	4.1	3.5	2.0	1.0	0.4	1.6200	1.6153	1.6319		37.2	98.6	31	Covered	40

TABLE 6.—LIGHT FLINT.

Melt. No.	Batch No.	% SiO_2.	% PbO.	% K_2O.	% Na_2O.	% CaO.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	ν.	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
29	A-2	53.9	36.7	6.0	1.0	1.96	0.3	1.57988	1.57583	1.58983	1.59816	41.6	99.5	54	Open	17
33	A-2	53.9	36.7	6.0	1.0	1.96	0.6	1.58484	1.58070	1.59509	1.60366	40.5	99.3	54	Open	15
52	A-2	53.9	36.7	6.0	1.0	1.96	0.4	1.59138	1.58726	1.60159	1.60998	41.3	99.0	53	Open	10
56	A-2	53.9	36.7	6.0	1.0	1.96	0.3	1.5803	1.5762	1.5902	1.5986	41.0	99.1	55	Open	10
188	A-4	53.9	35.2	7.64	1.0	1.96	0.3	1.5805	1.5765	1.5903		41.9	99.3	56	Open	0

TABLE 7.—DENSE FLINT.

Melt. No.	Batch No.	% SiO_2.	% PbO.	% K_2O.	% CaO.	% Na_2O.	% Sb_2O_3.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	ν.	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
65	C-2	39.9	48.8	6.8	4.8			0.2	1.64799	1.64272	1.66125	1.67259	35.0	99.1	51	Open	0
76	C-3	39.0	49.0	4.0	4.0	3.0	1.0	0.2	1.65555	1.65019	1.66922	1.68091	34.4	98.9	54	Covered	60

TABLE 8.—BARIUM FLINT.

Melt. No.	Batch No.	% SiO_2.	% PbO.	% K_2O.	% Na_2O.	% ZnO.	% B_2O_3.	% BaO.	% CaO.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	ν	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
135	H-2	53.69	16.71	8.31	1.69	2.53	2.68	14.27		0	1.56823	1.5648	1.5764		48.6	98.6	54	Open	10
145	H-3	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.4	1.5521	1.5489	1.5597	1.56630	51.0	99.0	50	Open	25
155	H-3*a*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.6	1.5496	1.5465	1.5571		51.9	99.3	53	Open	10
156	H-3*a*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.5	1.5567	1.5535	1.5644		51.0	99.4	53	Open	0
169	H-3*b*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.6	1.5582	1.5551	1.5660		51.2	99.5	52	Open	25
190	H-3*c*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.4	1.5529	1.5498	1.5603		52.6	99.6	85	Open	10
199	H-3*d*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.3	1.5542	1.5413	1.5510		56.3	99.3	50	Open	10
200	H-3*d*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.3	1.5484	1.5454	1.5557		53.3	99.8	52	Open	10
205	H-3*e*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.4	1.5503	1.5474	1.5579		52.5	99.3	50	Open	30
207	H-3*e*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.4	1.5493	1.5462	1.5566		53.0	99.7	74	Open	30
208	H-3*e*	58.69	12.71	8.31	1.69	2.53	1.68	14.27		0.4	1.5521	1.5491	1.5596		52.3		51	Open	0
217	H-3*f*	58.81	12.71	8.31	1.69	2.53	1.68	14.27	1.00	0.5	1.5488	1.5457	1.5561		52.7		51	Open	33
218	H-3*f*	58.81	12.71	8.31	1.69	2.53	1.68	12.27	1.00	0.5	1.5500	1.5470	1.5575		52.6		53	Open	33
223	H-4	58.8	13.71	8.31	1.7	2.53	1.68	12.27	1.00	0	1.5514	1.5483	1.5589		52.1		45	Open	30
224	H-4	58.8	13.71	8.31	1.7	2.53	1.68	12.27	1.00	0	1.5518	1.5487	1.5593		52.1		48	Open	25
245	H-4*a*	58.8	13.71	8.31	1.7	2.53	1.68	12.27	1.00	0.4	1.5545	1.5514	1.5620		52.3	99.2	38	Open	30
253	H-4*a*	58.8	13.71	8.31	1.7	2.53	1.68	12.27	1.00	0.4	1.5537	1.5506	1.5612		52.2	99.3	27	Covered	75
261	H-4	58.81	13.71	8.31	1.69	2.53	1.68	12.27	1.00		1.5544	1.5513	1.5618		52.6	99.0	31	Open	80
264	H-4	58.81	13.71	8.31	1.69	2.53	1.68	12.27	1.00		1.5531	1.5500	1.5606		51.7	99.1	32	Open	100

TABLE 9.—LIGHT CROWN.

Melt. No.	Batch No.	% SiO_2.	% B_2O_3.	% K_2O.	% Na_2O.	% BaO.	% ZnO.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	P.	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
20	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.2	1.5179	1.5153	1.5238	1.5286	60.9	99.0	60	Open	15
36	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.5	1.5151	1.5140	1.5226	1.5274	60.0	99.6	53	Open	15
41	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.5	1.5153	1.5128	1.5213	1.5261	60.5	98.9	50	Open	15
42	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.5	1.51656	1.51416	1.52255	1.52734	61.3	98.7	50	Open	5
43	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.5	1.51717	1.51462	1.52317	1.52791	62.5	98.6	50	Open	15
46	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.5	1.5165	1.5140	1.5225	1.5276	60.3	98.6	53	Open	15
49	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.2	1.52905	1.52638	1.53520	1.54006	60.0	98.9	53	Open	10
55	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.2	1.5179	1.5153	1.5239	1.5288	60.0	99.1	51	Open	10
71	D-1	68.5	3.5	5.0	12.0	9.7	1.0	0.4	1.51554	1.51297	1.52151	1.52633	60.4	98.5	49	Open	10
78	D-2	68.5	3.0	5.0	11.0	10.6	1.5	0.4	1.5155	1.51296	1.52157	1.52647	59.9	98.8	51	Open	0
80	D-2	68.5	3.0	5.0	11.0	10.6	1.5	0.4	1.5158	1.51326	1.52189	1.52680	59.8	99.1	53	Open	10
90	D-2	68.5	3.0	5.0	11.0	10.6	1.5	0.4	1.5160	1.51347	1.52207	1.62697	60.0	98.6	44	Open	10
91	D-2	68.5	3.0	5.0	11.0	10.6	1.5	0.4	1.51475	1.51223	1.52076	1.52556	60.2	98.8	51	Open	10
103	D-3	67.0	3.5	5.0	12.0	10.6	1.5	0.4	1.5175	1.51455	1.52319	1.52803	59.9	98.7	54	Open	10
113	D-3	67.0	3.5	5.0	12.0	10.6	1.5	0.4	1.51771	1.51528	1.52394		59.7	98.8	52	Open	40
123	D-3*b*	67.0	3.5	5.0	12.0	10.6	1.5	0.4	1.51708	1.5147	1.5234	1.52819	59.6	98.9	50	Open	40

TABLE 10.—BOROSILICATE.

Melt. No.	Batch No.	% SiO_2.	% B_2O_3.	% K_2O.	% Na_2O.	% CaO.	% BaO.	% ZnO.	% As_2O_3.	N_D.	N_C.	N_F	N_G.	ν.	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
40	G-2	69.5	8.9	8.39	8.2		3.01	0.25	0.31	1.51193	1.50949	1.51761	1.52210	63.1	98.8	50	Open	13
44	G-2	69.5	8.9	8.39	8.2		3.01	0.25	0.31	1.51254	1.51012	1.51816	1.52260	63.8	99.0	51	Open	15
47	G-2	69.5	8.9	8.39	8.2		3.01	0.25	0.31	1.5101	1.5077	1.5157	1.5200	64.0	98.3	51	Open	15
72	G-3	68.0	6.0	8.0	10.0		8.0	2.0	0.2	1.51718	1.51467	1.52307	1.53778	61.5	99.0	54	Open	10
83	G-3	68.0	6.0	6.0	10.0		8.0	2.0	0.2	1.51640	1.51390	1.52229	1.52701	61.6	97.8	76	Open	0
86	G-4	68.0	8.0	6.0	10.0		8.0	2.0	0.2	1.51966	1.51716	1.52555	1.53029	61.9	99.1	48	Open	0
92	G-4	68.0	8.0	6.0	10.0		8.0	2.0	0.2	1.52253	1.52015	1.52845	1.53321	63.0	99.0	58	Open	0
94	G-5	68.0	8.0	6.0	10.0		8.0	2.85	0.2	1.51997	1.51742	1.52584	1.53058	61.8	98.8	51	Open	30
187	G-6	64.2	11.0	8.27	9.45		7.08	2.85	0.2	1.5243	1.5219	1.5302		63.3	98.9	58	Open	0
201	G-7	64.2	13.0	8.27	9.45		5.08	2.85	0.2	1.5220	1.5196	1.5277		64.2	99.7	56	Open	10
210	G-8	64.2	11.0	8.27	9.45	1.0	6.08	2.85	0.2	1.5240	1.5216	1.5298		63.4	99.1	50	Open	40
240	G-9	64.2	12.5	8.27	9.45	1.0	4.58	2.85	0.4	1.5245	1.5221	1.5303		64.0	98.8	35	Covered	60
241	G-9	64.2	12.5	8.27	9.45	1.0	4.58	2.85	0.4	1.5252	1.5241	1.5303		64.4	99.0	38	Covered	75

TABLE 11.—LIGHT BARIUM CROWN.

Melt. No.	Batch No.	% SiO_2.	% B_2O_3.	% K_2O.	% Na_2O.	% ZnO.	% BaO.	% CaO.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	ν.	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
27	E-1	48.1	4.5	7.5	1.0	10.1	28.3	2.0	0.4	1.5615	1.55682	1.56828	1.57367	58.1	98.0	52	Open	15
30	E-1	48.1	4.5	7.5	1.0	10.1	28.3		0.4	1.57038	1.56740	1.57740	1.58299	57.0	95.0	56	Open	15
50	E-1	48.1	4.5	7.5	1.0	10.1	28.3		0.4	1.5701	1.5669	1.5768	1.5827	57.6	98.3	56	Open	10
51	E-1	48.1	4.5	7.5	1.0	10.1	28.3		0.4	1.56918	1.5663	1.5762	1.5818	57.3	98.9	52	Open	10
57	E-1	48.1	4.5	7.5	1.0	10.1	28.3		0.4	1.5698	1.5680	1.5779	1.5835	57.4	97.4	50	Open	10
59	E-1	48.1	4.5	7.5	1.0	10.1	28.3	2.0	0.4	1.57202	1.56908	1.57907	1.58479	57.3	97.9	52	Open	10
66	E-1	48.1	4.5	7.5	1.0	10.1	28.3		0.4	1.57050	1.56758	1.57763	1.58321	56.8	97.8	51	Open	10
87	E-2	48.0	4.0	6.1	2.0	10.0	29.5		1.4	1.57340	1.57043	1.58057	1.58625	56.7	98.7	52	Open	0
105	E-1	48.0	4.5	6.1	2.0	10.0	29.5		1.4	1.57542	1.57253	1.58272	1.58855	57.5	98.3	52	Open	50
115	E-2*a*	48.0	4.0	6.1	2.0	10.0	29.5		1.4	1.57420	1.57126	1.58139	1.58720	56.7	97.5	49	Open	50
116	E-2*a*	48.0	4.0	6.1	2.0	10.0	29.5		1.4	1.57409	1.57112	1.58125	1.58703	56.6	98.6	51	Open	50
117	E-2*a*	48.0	4.0	6.1	2.0	10.0	29.5		1.4	1.57427	1.57122	1.58133		56.8	98.1	50	Open	10
121	E-2*a*	48.0	4.0	6.1	2.0	10.0	29.5		1.4	1.56752	1.56468	1.57465	1.58036	57.0	99.5	48	Open	10
125	E-2B	48.0	4.0	6.1	2.0	10.0	29.5		1.4	1.57511	1.57213	1.58229	1.58813	56.6	98.7	50	Open	10
126	E-3	47.6	3.95	6.0	1.98	9.8	30.5	2.0	1.5	1.57508	1.57207	1.58225	1.58806	56.3	98.8	52	Open	10
133	E-3	47.6	3.95	6.0	1.98	9.8	30.5		1.5	1.57850	1.57547	1.58580	1.59123	56.0	98.7	51	Open	10
136	E-3	47.6	3.95	6.0	1.98	9.8	30.5		0.0	1.57712	1.57413	1.58432	1.59916	56.7	97.8	53	Open	10
138	E-3	47.6	3.95	6.0	1.98	9.8	30.5		0.0	1.5759	1.57271	1.58284		56.6	98.3	51	Open	10
139	E-3	47.6	3.95	6.0	1.98	9.8	30.5		0.0	1.5765	1.57354	1.58369		56.8	98.3	58	Open	10
140	E-3	47.6	3.95	6.0	1.98	9.8	30.5		0.0	1.58045	1.57748	1.58781		56.4	97.9	56	Open	10
148	E-3*a*	47.6	3.95	6.0	1.98	9.8	30.5		0.6	1.5755	1.57237	1.58253		56.5	98.4	55	Open	25
149	E-3*a*	47.6	3.95	6.0	1.98	9.8	30.5		0.5	1.5995	1.59616	1.50714	1.61348	54.6	98.1	55	Open	25
150	E-3*b*	47.6	3.95	6.0	1.98	9.8	30.5		0.5	1.5789	1.57623	1.58652	1.59243	56.5	99.1	54	Open	25
152	E-4	46.0	5.5	6.1	2.0	10.5	29.5		0.5	1.5790	1.5760	1.5862		56.5	98.5	55	Open	10
153	E-4	46.0	5.5	6.1	2.0	10.5	29.5		0.5	1.5771	1.5742	1.5842		56.7	98.4	55	Open	10
154	E-4	46.0	5.5	6.1	2.0	10.5	29.5		0.5	1.5777	1.5747	1.5848	1.59075	57.1	98.7	55	Open	25
172	E-4	46.0	5.5	6.1	2.0	10.5	29.5		0.5	1.5826	1.5796	1.5899		56.7	97.8	60	Open	25
173	E-4*a*	46.0	5.5	6.1	2.0	10.5	29.5		0.5	1.5831	1.5801	1.5904		56.6	98.5	55	Open	25
175	E-5	46.3	6.5	7.2	2.0	8.5	29.5		0.5	1.5837	1.5796	1.5899		56.4	97.5	55	Open	10
178	E-6	48.1	4.57	8.0	2.0	10.4	26.5		0.4	1.5741	1.5711	1.5812		56.5	98.3	59	Open	10

TABLE 11—LIGHT BARIUM CROWN (*Continued*).

195	E-6	48.1	4.57	8.0	2.0	10.4	26.5		0.4	1.5693	1.5664	1.5763		57.6	98.0	58	Open	10
196	E-5*a*	46.3	6.5	7.2	2.0	8.5	29.5		0.4	1.5766	1.5737	1.5837		57.6	96.8	55	Open	10
229	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5755	1.5726	1.5826		57.2	98.5	39	Open	50
231	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5724	1.5695	1.5795		56.9	98.5	44	Covered	50
232	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5750	1.5720	1.5820		57.7	98.2	44	Covered	50
233	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5723	1.5694	1.5793		57.9	98.8	44	Covered	50
234	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5705	1.5676	1.5774		58.5	98.8	34	Covered	50
236	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5753	1.5724	1.5824		57.5	98.1	36	Covered	50
242	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5728	1.5699	1.5798		57.7	98.8	35	Covered	50
243	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5737	1.5706	1.5806		57.5	99.2	33	Open	10
237	E-7	48.1	4.6	8.0	2.0	8.4	26.5	2.0	0.5	1.5725	1.5696	1.5795		57.9	98.6	35	Covered	50
238	E-7	48.1	4.57	8.0	2.0	8.4	26.5	2.0	0.5	1.5764	1.5734	1.5835		57.1	98.7	36	Covered	50
244	E-7	48.1	4.57	8.0	2.0	8.4	26.5	2.0	0.5	1.5717	1.5688	1.5787		57.5	99.0	34	Open	10
250	E-7	48.1	4.57	8.0	2.0	8.4	26.5	2.0	0.5	1.5723	1.5694	1.5794		57.2	99.0	35	Covered	60
252	E-7	48.1	4.57	8.0	2.0	8.4	26.5	2.0	0.5	1.5701	1.5671	1.5772		56.4	98.8	35	Covered	60
257	E-7	48.1	4.57	8.0	2.0	8.4	26.5	2.0	0.5	1.5721	1.5692	1.5791		57.8	98.8	38	Covered	60

Table 12.—DENSE BARIUM CROWN.

Melt. No.	Batch No.	% SiO_2.	% B_2O_3.	% K_2O.	% CaO.	% ZnO.	% PbO.	% BaO.	% Al_2O_3.	% As_2O_3.	N_D.	N_C.	N_F.	N_G.	ν.	Transmission. T.	Melting time.	Type of pot.	Per cent of cullet used.
53	F-1	39.6	5.0		2.0	7.7	3.0	44.0		0.4	1.59051	1.58736	1.59773	1.60358	57.0	88.1	57	Open	10
122	F-2*b*	37.0	5.0	2.6	2.0	7.7	3.0	44.0		0.7	1.62146	1.61809	1.62968	1.63636	53.6	91.0	51	Open	10
124	F-2*b*	37.0	5.0	2.6		7.7	3.0	44.0		0.7	1.6199	1.61779	1.62939	1.63605	53.5	96.5	50	Open	10
127	F-2*b*	37.0	5.0	2.6		7.7	3.0	44.0		0.7	1.6177	1.6143	1.6258		53.9	96.6	51	Open	10
132	F-2*c*	37.0	5.0	2.6		7.7	3.0	44.0		0.7	1.6242	1.6208	1.6375		53.5	96.8	52	Open	10
151	F-3	37.0	5.0	2.6		7.7		47.0		0.7	1.6177	1.6144	1.6256		55.2	95.4	55	Open	25
171	F-4*a*	33.5	10.5	2.6		7.5		42.5	6.0	0.7	1.6040	1.6009	1.6115		57.1	91.1	63	Open	10
186	F-6	39.0	5.0	2.6	2.0	7.0		45.0	1.0	0.4	1.6098	1.60658	1.61749		55.9	96.0	62	Open	10
191	F-6*a*	39.0	5.0			7.0		45.0	1.0	0.4	1.6046	1.6015	1.6121		57.0	97.2	56	Open	10
216	F-9	34.5	9.1		2.0	7.8		42.0	4.0	0.6	1.6055	1.6024	1.6131		56.8	97.5	37	Open	10

batch weights and hence are not analyses of the finished glasses. This is due partly to undetermined changes in the raw materials as they lie in storage and partly to volatilization of materials in melting the glass.

The compositions used and indices obtained at the Bureau of Standards' factory are given in Tables 5 to 12. The optical properties were determined at the Bureau of Standards, Washington, D. C. In these tables the melting time in hours is shown, also the type of pot and the per cent of cullet used. All the data given in these tables were obtained from melts approximating 1000 pounds of glass.

BUREAU OF STANDARDS,
PITTSBURGH, PA.

THE EFFECT OF ELECTROLYTES ON THE PROPERTIES OF GRAPHITE CRUCIBLE BODIES.[1]

By H. G. Schurecht.

Outline of Investigation.

The effect of electrolytes on the properties of graphite crucible bodies was studied by adding the electrolyte to each body in three different ways:

1. By pugging the body to stiff-mud consistency and then adding the electrolyte.

2. By wet-grinding the flake graphite with electrolyte and water in a wet pan, and then mixing the graphite thus treated with the clay and other constituents of the body.

3. By preparing slips with graphite and clay and then adding the electrolyte.

The following bodies were studied:

Table 1.—Composition of Bodies.

Number	1	2	3	4	5	6	7	8
	%	%	%	%	%	%	%	%
Alabama flake graphite	55	55	..	..	55	..	..	55
Alabama coked graphite	..	..	55	..	..	..	55	..
Alabama deflocculated graphite	..	..	..	55	..	..	..	..
Ceylon graphite	..	..	..	..	..	55	..	..
Dorset clay	35	..	..	..	45	45	45	..
Mississippi clay	..	35	35	35	..	..	..	45
Sand	5	5	5	5	..	..	..	..
Kaolin	5	5	5	5	..	..	..	..

The electrolytes used were NaOH and HCl. To study their effect on bodies in the plastic state the following properties were determined:

1. Working properties as judged by feel and behavior in jiggering crucibles.

[1] By permission of the Director, U. S. Bureau of Mines.

2. Dry transverse strength.
3. Dry density.
4. Dry porosity.
5. Drying volume shrinkage.

To determine the effect of NaOH on the viscosity of Bodies Nos. 5, 6, 7 and 8, the graphite was screened through a 40-mesh sieve and slips were prepared containing three parts solid and five parts water with varying percentages of NaOH. After standing twenty-four hours the slips were tested with the flow-viscosimeter, using an orifice of one-eighth inch. The viscosities were calculated by the use of the following formula:

$$V = S \times \frac{T_s}{T_w} \text{ in which}$$

V = Viscosity of slip.
S = Specific gravity of slip.
T_s = Time required for 250 cc. of slip at 18° C to flow through the orifice
T_w = Time required for 250 cc. of water at 18° C to flow through the orifice.

Results of the Investigation.

Working Properties.—When NaOH was added to Body No. 1, containing Dorset clay, it lost considerable plasticity. Attempts to make crucibles from this body, when NaOH was used, proved unsuccessful. On the other hand, the addition of HCl developed a body with better working properties than when untreated.

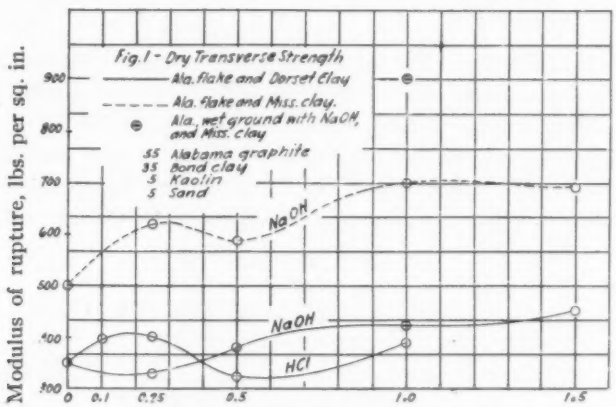
Adding NaOH to bodies containing Mississippi clay improved the working properties—its effect on this clay being the opposite of that on the Dorset clay.

Body No. 2 (containing no added electrolyte), with 55 per cent Alabama flake graphite and 35 per cent Mississippi bond clay was molded with difficulty—the body tearing badly from the jigger-tool and showing many laminations on the outside surface of the crucible. These difficulties were largely overcome by the use of one per cent of NaOH (in terms of clay).

In Body No. 4 the flake graphite was treated by adding one per cent NaOH and grinding in a wet pan for one and one-half

hours. Graphite thus treated developed considerable plasticity, had mechanical strength when dry, and when used to replace flake graphite produced a body whose jiggering behavior was much better than that of the body containing untreated flake graphite.

Dry Transverse Strength.—Adding NaOH to bodies containing Dorset clay at first decreased and, with larger additions, increased the dry strength of the body (see Fig. 1). This effect of



Per cent electrolyte in terms of clay.

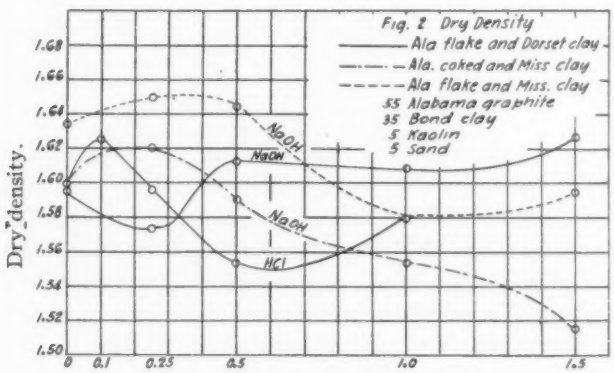
alkalies was probably due to flocculation of the clay with the smaller additions and to deflocculation with larger additions. As the grains in flocculated clay are more or less aggregates of many fine particles, we would expect this body to be mechanically weak. The deflocculated clay is extremely fine grained and, therefore, it would seem that a denser body can be molded and the mechanical strength thus increased. The effect of acids is the opposite of that produced by alkalies so it appears that the changes produced are functions of the alkalinity or acidity of the bodies.

When alkalies were added to bodies containing Mississippi clay the strength was increased. The effect of alkalies, therefore, seems to vary with different clays. This may be due to a difference in the initial alkalinity or acidity of the clays.

When the graphite, treated by pugging with NaOH, was added

to the body in the place of flake graphite, the modulus of rupture was 900 pounds per square inch. As the body containing flake graphite had a maximum strength of 700 pounds per square inch when treated with NaOH, it appears that there are certain advantages, as far as strength is concerned, gained by first pugging the graphite with NaOH before mixing with the clay. This increase in strength was partly due to the finer grains caused by wet grinding, but may also have been due to colloidal graphite produced by grinding.[1]

Density.—When NaOH in varying percentages was added to the body containing Dorset clay, its effect was to decrease the density when a small percentage (0.25 per cent in terms of clay) was used and then increase the density when larger percentages were used. HCl acted oppositely, in increasing the density with small additions and decreasing the density with the larger additions (see Fig. 2).



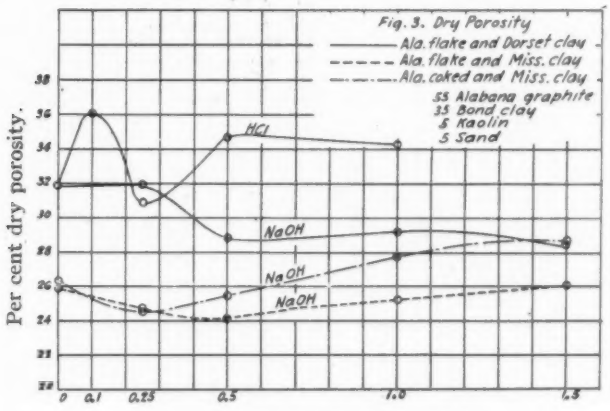
Per cent electrolyte in terms of clay.

The effect of NaOH on bodies containing Mississippi clay was similar to the effect of HCl on bodies containing Dorset clay.

Porosity.—Small percentages of HCl made the body containing Dorset clay more open while the addition of a larger per-

[1] E. G. Acheson, Brit. 111,434, Nov. 28, 1917, "Method of Deflocculating Solid Materials."

centage produced a less porous body (see Fig. 3). The alkali, on the other hand, made the body "tighter."



Per cent electrolyte in terms of clay.

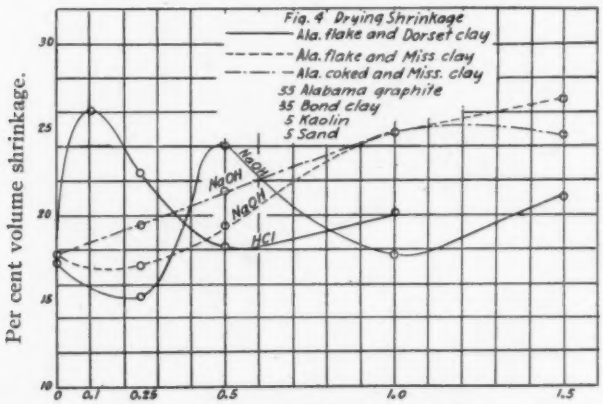
The effect of NaOH on bodies containing Alabama flake and coked graphites with Mississippi clay was to decrease the porosity when small percentages were used and to increase the porosity when larger percentages were used.

Drying Shrinkage.—NaOH seemed to increase the shrinkage of bodies containing Mississippi clay and to first decrease and then increase the shrinkage when Dorset clay was used (see Fig. 4). The acid again acted oppositely to that of the alkali.

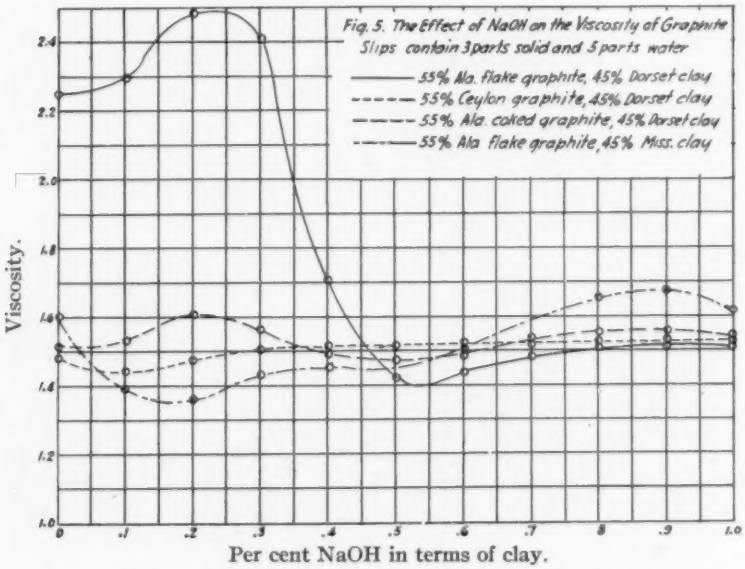
Six No. 60 graphite crucibles, containing one per cent NaOH, in terms of clay, were made. In drying these were set upright, the rims being unprotected. This drying treatment was more severe than that used in practice—where the rims are protected by setting the crucibles upside down during drying. The crucibles showed no signs of cracking—as was noted by Staley[1] in clays containing alkalies. Staley, however, worked with low-grade clays which had a tendency to crack in drying, and, furthermore, the test pieces he used contained 100 per cent clay. In the pres-

[1] H. F. Staley, "The Effect of the Addition of Salts on the Drying Properties of Clays," *Trans. Am. Ceram. Soc.*, **17**, 697–711 (1915). Discussion, *J. Am. Ceram. Soc.*, **1**, 214 (1918).

ent case high-grade clays were used and the bodies contained 60 per cent of non-plastic material—which may account for the difference.



Viscosity.—When NaOH was added to Body No. 5 (containing Dorset clay and Alabama flake graphite) the viscosity was at first increased and when more than 0.3 per cent was added it was decreased (see Fig. 5).



When Ceylon graphite or Alabama coked graphite were used in the place of flake graphite, this increase in viscosity with small additions of electrolyte was not nearly so pronounced. It appears that the effect of flake graphite itself or of some constituents of the graphite (possibly the oils used in flotation) on the clay were factors which caused this increase in viscosity of the slip.

Where Alabama graphite was used with Mississippi clay, the viscosity of the slip was decreased upon adding small percentages of NaOH, this having been most pronounced when 0.2 per cent (in terms of the clay) was used. With this clay no increase in viscosity, such as was obtained with the Dorset clay, was observed.

In attempting to cast body No. 1 with 0.2 per cent electrolyte, it was found that the shrinkage was excessive—causing many cracks in the trial crucibles. Bodies containing 0.3 to 0.4 per cent NaOH gave the best results. When more than 0.5 per cent NaOH was used, the graphite would not remain in suspension and the casting proceeded very slowly. With this content of electrolyte only thin-walled vessels could be cast.

It was noted that bodies containing Ceylon graphite could be casted more easily than those containing Alabama flake graphite.

Summary.

The addition of NaOH to graphite-crucible bodies containing Dorset bond clay spoiled the working properties of the bodies, while the effect of the same electrolyte on bodies containing Mississippi bond clay was to improve their moldability. HCl had an effect opposite to that of NaOH and improved the working properties of the body containing Dorset clay.

The effect of small additions of NaOH to bodies containing Dorset clay was to decrease the dry transverse strength but, where larger percentages of electrolyte were used, the opposite was true. The effect of NaOH on the body containing Mississippi clay was to increase the strength.

An improvement in dry strength was gained by first grinding the flake graphite with the NaOH and water before mixing with the clay.

Small additions of NaOH decreased the density of bodies containing Dorset clay and increased the density of bodies containing Mississippi clay. Where larger additions of this electrolyte were used, the opposite effects were produced. HCl produced opposite effects to that of NaOH.

The effect of small amounts of HCl was to make the body containing Dorset clay more open while adding a larger percentage made the body less porous. NaOH made this same body less porous. The effect of NaOH on bodies containing Mississippi clay was to decrease the porosity when small percentages were used and increase the same when larger amounts were used.

NaOH seemed to increase the shrinkage of bodies containing Mississippi clay and to first decrease and then increase the shrinkage when Dorset clay was used. The acid again acted oppositely to that of the alkali.

When NaOH was added to slips containing Alabama flake graphite and Dorset clay, the viscosity was increased, but upon adding more alkali, it was again decreased. When Ceylon graphite or Alabama coked graphite was used in the place of Alabama flake graphite, this increase in viscosity was not noted. Where Mississippi clay was used in the place of Dorset clay, the effect of small percentages of NaOH was to decrease the viscosity.

Bureau of Mines,
Mining Experiment Station,
Columbus Ohio

RADIOACTIVE BRICKS.

By H. J. Knollman.

The manufacture of radioactive clay bricks or briquettes has its chief interest from a ceramic viewpoint in the fact that a clay product is being made and used for an unusual purpose. This, therefore, also entails some work of an unusual nature. So while some of the subject matter of this paper is outside the silicate field, nevertheless the main features fall within the scope of ceramics.

Radium, because of its value, scarcity and wonderful properties, occupies a place of much interest in popular as well as scientific circles. Its market value is about $100 a milligram, or over two and a half million dollars an ounce. There is considerably less than a pound of prepared radium in the world, and in the United States, there is prepared from a few grains up to about 50 grams per year. To produce a gram of radium element, from 400 to 500 tons of carnotite ore are required on an average. It is prepared in this country, chiefly from the carnotite ores of Utah and Colorado. This ore is treated a few hundred times with acids, requiring months of time. A few hundred additional fractional crystallizations must be made before the radium element is obtained in a concentrated form. It may finally be precipitated in a finely divided state as the insoluble radium sulphate, intimately mixed with barium sulphate, from which it is extremely hard to separate. It is about the scarcest article in the world and the most valuable, since not only are the ores scarce, but the yield of the element is so small.

Becquerel discovered the radioactivity of uranium in 1896, and M. and Mme. Curie discovered radium and polonium shortly after. We now have over thirty of these wonderful substances with their almost life-like properties. Of these radium is the most important, followed by uranium, thorium and actinium.

Radioactivity is the spontaneous successive disintegration of radioactive atoms, with emission of "rays." In its characteristic

property of radioactivity, radium is absolutely independent of its environment, whether it be in its natural mineral state, in an isolated state, or mixed with other substances. In all its various compounds it is constantly giving off alpha rays and emanation at a uniform rate, which is not affected by extremes of heat or cold or of pressure, by the strongest reagents, by the action of powerful explosives or intense electrical discharges. The rays emitted from radium are of three types, the alpha, beta and gamma. The alpha rays are positively charged helium atoms shot out in all directions in the form of continuous volleys of tiny projectiles, with velocities of about 12,000 miles per second. They are completely absorbed by a very thin screen or membrane. The beta rays are negative electrons emitted with velocities from one-third to nearly the velocity of light, 186,000 miles per second. They are harder to absorb than the alpha rays, the harder beta rays requiring over a millimeter of lead for their absorption. The gamma rays are not considered to be particles of matter at all, but rather waves in the ether resembling the X-rays. They are the most penetrating form of radiation, the hard gamma rays from radium C requiring over 13 centimeters of lead for their absorption. Over ninety-five per cent of the energy of radiation from radium and its products is in the form of corpuscular alpha radiation, however.

The first disintegration product from radium is emanation, which it constantly gives off. It is an inert gas, similar in its properties to helium and argon, and it obeys all the laws of a true gas. It can be collected, confined and handled in ordinary containers and is quite soluble in water. Emanation in turn disintegrates into alpha particles and radium A, from which in the same way come radium B, radium C, radium D, radium E and radium F, in succession, with varying periods of average life. It is from these products, rather than from radium itself, that the beta and gamma rays are given off.

When a radioactive element changes, it does not as a rule do so once only, but there are several successive changes following one another. Whereas the first change is slow, the subsequent changes often are relatively more rapid. At any stage, the total amount of radioactivity is constant and unaffected, although it

may be divided into several parts. Hence, radioactivity is due to equilibrium between continuous and opposing changes, decay and regeneration. Thus, while the emanation disintegrates or decays, radium is spontaneously manufacturing a fresh supply. So small a fraction of the whole is changing, however, that the main part of the radium will remain unchanged after hundreds of years. The radioactivity of emanation rapidly decays away so that in four days it is one-half as active, in eight days one-fourth as active, and so on, until it is practically zero at the end of a month. The time required for a radioactive body to lose one-half of its activity is known as the period of average life—which for radium is about 1800 years and for uranium, eight million years.

Radium, because of its long life and because of the number of short-lived products which follow it, emitting the different rays, is the most useful radio-element. One of its largest uses is in radium luminous compounds for use on watch dials, compasses and instrument dials. It also finds extensive use in the treatment of dermatological growths, and in the therapy of malignant growths. Particularly in cancer, it is used externally, the hard beta and gamma rays being utilized for this purpose.

It is for internal use, however, that radium emanation has become important as a therapeutic agent. Water charged with radium emanation, when taken, scatters this emanation through the body and seems to arouse all the cells of the body to a greater activity, being a sort of tonic to them all. In general, the emanation increases the activity of certain enzymes, promotes tissue oxidation and the general metabolism, and helps in the elimination of waste products. It is an effective agent in the treatment of such diseases as gout, arthritis, rheumatism, neuralgias, neuritis, anemia, and troubles of this nature. Many radioactive springs containing mere traces of mineral solids have long enjoyed a reputation in the treatment of various diseases of this kind.

Although various methods have been adopted for the introduction of radium emanation into the body, the drinking of radioactive water, natural or artificial, is the simplest. Natural radioactive springs are charged with radium emanation by contact with radium minerals. These natural waters when bottled and transported lose their activity speedily, owing to the rapid disintegra-

tion of the emanation. The artificial method has the advantage of providing a source for the renewal of the emanation from day to day. By using an insoluble salt of radium, it can be used repeatedly and its use continued indefinitely.

The most satisfactory and simplest method of charging water with emanation is to incorporate definite amounts of the insoluble $RaSO_4$ in a finely subdivided state throughout the clay, mold or press into briquettes or rods, and then burn them. When placed in water in tightly closed bottles, these bricks or plates, as they are generally called, give off the emanation, which dissolves in the water, the quantity depending upon the radium content and the time of submersion. Since radium is a very permanent body, losing only one-half its weight in about eighteen hundred years, these plates retain their activity indefinitely.

The strength of radioactive water is usually given in Mache Units per liter. A Mache Unit equals 0.001 electrostatic unit, one of which equals 3.33×10^{-10} amperes, and is the standard unit adopted. Bricks of different strengths are manufactured, the usual strengths varying from 500 to 5000 Mache Units each per 24-hour yield. These will take a corresponding amount of radium element, varying from a few to several hundred micrograms.

While a given amount of radium always gives off a uniform amount of emanation, the proportion given out by the insoluble salt depends largely upon its state of subdivision. In dense, compact form, radium sulphate will only yield $2^1/_2$ per cent, while if it is finely powdered and spread so that it presents a large surface, 10 per cent can be obtained. This latter result can be obtained in a clay body with a fairly large absorption, since the amount of surface is then at a maximum. Every part of the radium sulphate, not the surface only, is giving out the three types of rays, and the alpha rays especially will be absorbed by the dense and heavy radium sulphate, unless it is spread out. The $RaSO_4$ is, therefore, precipitated along with the $BaSO_4$ in a finely divided state, thoroughly dried, and is then ground to an almost impalpable powder.

The basis of "Radio-Rem" bricks or plates, as they are gen-

erally called, is Albany slip clay—more than 50 per cent of the body being made out of this clay. Besides the Albany clay, a rather sandy non-plastic clay is used and also some infusorial earth. The purpose of the infusorial earth is to cut down excessive plasticity, and also to render the body more porous. To these clays, the radium-barium sulphate is added in varying amounts, depending upon the radioactive strength desired. These clays are each ground dry so as to pass a 40-mesh sieve before being used. If any broken plates are used in the mix, they are ground up to a like fineness. As a matter of fact, the composition of the body is relatively unimportant. Any good clean clay, with a low amount of soluble salts, and maturing with the addition of less plastic clays and non-plastic to a hard body at about cone 08, can be used.

The prepared clays are then weighed out, the total check weighed, the radium-barium sulphate is added, and the whole is placed in ordinary porcelain jar mills with enough flint pebbles to insure thorough mixing. The total weight per batch in the mill seldom exceeds 1000 grams, which is equivalent to 25 plates. The whole is mixed dry for a few hours, is then removed from the mill and the pebbles carefully brushed off. Owing to its value and the fact that a minute amount of the radium element goes a long way in its effects, great care must be exercised throughout the process of manufacture to avoid even very small losses.

The mixture is then check-weighed so that the weight corresponds to the original weight. Water is then added and the mixture thoroughly worked up with a large spatula to a uniform crumbly mass. From 26 to 27 per cent water is required for proper consistency, the best consistency being midway between that required for the dry-press process and the stiff-mud process. This is an important step, as just a little too much or not quite enough water results in an inferior product. If too little water is used, the pressed body will be crumbly, will break and crack easily, and will burn soft and punky at this temperature. If, on the other hand, just a little too much water is used, the mix will ball up into lumps, the plate when pressed will be too soft to handle, and it will also burn soft and punky at cone 08. Any large lumps in the mix are broken up and the entire mass is made as

uniform as possible. If not obtainable otherwise, the mix can be made uniform by passing it through about a 16-mesh sieve.

The total weight is next obtained and the exact percentage of water is then calculated. The basis of the calculation is 40 grams dry weight per plate. Each individual plate is then weighed up to the nearest tenth of a gram, the main batch being kept covered with a tight fitting lid as much as possible. By so doing, very little drying out takes place and the mixture is kept uniform in moisture content until the entire batch is weighed up. The plates are pressed on a hand press, care being taken to spread the mixture as uniformly as possible in the die before pressing. The dimensions of the die are $3^3/_4'' \times 1^1/_4'' \times {}^3/_8''$, with corrugated surfaces on the top and bottom sides. This is also the approximate size of the burned plate, since the shrinkage is comparatively slight. The plates are then dried out, no special precautions being necessary. Owing to their small size, it is seldom necessary to use a dryer and open air drying is sufficient.

The plates are burned in small laboratory kilns of the muffle type, such as the R. & H. China Muffle or Caulkins Muffle kiln. They are burned to cone 08 in from eight to ten hours, and the same length of time is required in the cooling. Natural gas is preferred, although any fuel may be used, provided the burn is kept thoroughly oxidizing. Care must be taken to maintain thorough oxidizing conditions, for if there is any reduction whatever, the $RaSO_4$ is easily reduced to $RaSO_3$, which is soluble in water and the radium salt, together with its emanation, is lost after the first immersion of the plate in water. Flashing must be avoided for the same reason.

Best results are obtained when the plates are burned between cones 010 and 06, cone 08 giving most satisfactory results. Above cone 06, the yield in emanation decreases. At cone 1, only about 30 per cent of the activity is obtained. Since, however, a given amount of radium always gives off a fixed definite amount of emanation and alpha rays, no matter what is its environment, the emanation must be absorbed or occluded in some way. This is what happens at cone 1. The plates must be burned at a low temperature so that a minimum amount of fluxing action takes place—just enough to give a good commercial hard body which

will stand a little rough usage. The presence of glassy constituents, fluxes of iron, etc., forms an impervious seal to the alpha rays, so that they are kept within the plate. The water does not penetrate these sealed pores, and since the alpha rays are stopped by a thin membrane, the effect of the alpha radiation in such instances is lost. Since 95 per cent of the energy of radiation is in the form of the alpha radiation, this effect may be considerable. Reduction in the radioactivity was especially noticeable in some trial whiteware bodies burned to cones 1 and 3, in which a large amount of feldspar and cornwall stone were used.

The plates upon removal from the kiln are washed in running water for several hours in order to eliminate any soluble salts that may be present. They are then dried and are ready for testing. When used by the patient, the plates are placed in a tightly stoppered bottle of about one-half pint capacity, the bottle is then completely filled with water and the stopper inserted. The water is then drunk by the patient at specified intervals.

It was thought for some time that the absorption and porosity of the plates played a very important part in the yield of emanation, as expressed in Mache units. More exhaustive researches showed, however, that the standardization of the radium-barium salt used, the degree of fineness of the salt and materials, the temperature of burning, and the final testing of the burned plate had a much more important effect than the porosity of the plate. All other factors being constant, the yield is the same, no matter what the porosity, provided the plate is porous enough to allow the water to penetrate thoroughly through the entire plate. At cone 08, absorptions ranging from 15 to 40 per cent gave the same yield in Mache units per day, provided all the materials used were the same, and the range in composition was not great enough to materially affect the vitrification.

One of the chief effects of radioactive bodies and their disintegration products is to produce an ionization of the atoms of whatever substance the rays penetrate. Hence, any electrified object has its electricity rapidly discharged in the neighborhood of a radioactive substance. The instrument generally employed to detect this effect is the gold-leaf electroscope, which is capable of so great refinement that it affords the most delicate and sensitive

test that it is possible to employ for the detection of radioactivity. This principle is made use of not only in testing the strength of the radium salts used, but also to test the burned plates, or rather the radioactivity of the water which has been in contact with the plates. The radioactivity of the water is measured by a fontactoscope, which is an electroscope with a chamber for ionized air and a scale for measuring and timing the discharge. The fontactoscope is first standardized by testing a solution of a known amount of radium element, which has been sealed for thirty days, as it is then in radioactive equilibrium. After a standard has been obtained, the radioactive strength of any water containing emanation can be tested, measured and calculated.

Great care must be exercised in sampling the water. When water with emanation in solution is shaken up or otherwise disturbed, from 10 to 30 per cent of the emanation in the water may be lost, due to diffusion of the emanation from out of the water. When tested, the water is first carefully drawn from the bottle by means of a vacuum into a closed container, where it is then purposely shaken up to release the emanation from the water, from where it is then pumped into the ionization chamber of the fontactoscope. Then at definite specified time intervals, corresponding to the time intervals of the standard, the gold leaf is given a static charge produced by the simple ordinary method of rubbing two dissimilar bodies together and separating them. As the gold leaf collapses, due to the ionization produced by the radium rays, it moves across the scale in the fontactoscope. The time required for it to move across this scale is the time of discharge, which is obtained by the use of a stop-watch. The strength in Mache units per day is then calculated.

Special precautions in the testing of the plates must be taken or else erratic if not erroneous results will be obtained. No tests should be made upon an immersed plate until the third or fourth day, the results being too low on the first few days, since radioactive equilibrium has not been established, the period of average life for emanation being 3.8 days. The bottle containing the plate to be tested must be emptied and refilled with fresh water at every 24-hour interval. If refilled in a shorter time interval, the water remaining in the pores of the plate, which is not in-

considerable, will not have a full 24-hour emanation charge, so that if a test is made on the succeeding day, low results will be obtained, due to this factor. Likewise, if a plate is left in the water longer than 24 hours, and the bottle is then refilled, it cannot be tested accurately on the succeeding days, since the pore water contains more than a 24-hour charge, causing the resultant readings to be too high. These troubles are avoided by refilling the bottle exactly every 24 hours.

The method of charging the gold leaf in the fontactoscope is important. It should always be charged just sufficiently to bring it over to the extreme edge of the scale. It should be brought over in one charge, and not be charged in steps, so as to swing the gold leaf back and forth across the scale, for in so doing, the rate of ionization is retarded or interfered with, causing the speed of collapse of the leaf, or rather the rate of discharge to be slow, thus giving a low result. High humidity has the same general effect. When the humidity is high, the charging of the gold leaf becomes so difficult that if it is charged at all it will discharge erratically, giving unreliable results.

Although the manufacture of radioactive bricks presents no special difficulties from the ceramic standpoint, the outstanding factors are the accuracy and extreme care required to avoid even small losses in each step of the process of manufacture, as well as the precautions necessary for the correct testing of the bricks, all of which have a direct bearing upon the amount of radium element necessary to produce a plate of definite strength in Mache units per day.

SCHIEFFELIN & CO.,
NEW YORK, N. Y.

COMMUNICATED DISCUSSIONS.

CHAS. H. VIOL: The results obtained by the London Radium Institute would seem to indicate that the use of very strong radium emanation solutions is advantageous, their dosage for chronic arthritis being the daily administration of one-fourth liter of radium emanation water containing not less than one millicurie of radium emanation per liter, this being equivalent to about 700,000 Mache units of radium emanation per dose per day.

Our own inclination has been to recommend a dosage inter-

mediate between this high dosage of the London Radium Institute and the low dosage which can be obtained by the use of radioactive bricks; and to prepare such emanation solution most economically we have preferred to place the radium salt in a solution, securing the emanation in aqueous solution by a suitable arrangement of vessels which permits of the radium emanation being passed in a closed circuit, bubbling through the water which is to be made radioactive. This method permits of the utilization of fifty per cent or more of the emanation produced, and is consequently at least four times more effective in this respect than the radioactive bricks.

STANDARD CHEMICAL CO.,
PITTSBURGH, PA.

H. J. KNOLLMAN: While it is true that the method of obtaining emanation from a solution of a radium salt and bubbling it through the water to be drunk is more economical, yet it is not at all a practical method for the ordinary person who wants to have radioactive water at home or who wishes to carry the apparatus around with him. The method of immersing radioactive bricks in tightly stoppered bottles provides a convenient permanent source of emanation, which can be obtained by the patient at any time or place. It is also quite possible to produce radioactive bricks of considerably higher strengths than those given as being the usual strengths of bricks manufactured.

SOME PROPERTIES OF BOND CLAYS FOR GRAPHITE CRUCIBLES.[1]

By M. C. Booze.

Introduction.

During the war, the problem of securing materials suitable for the manufacture of graphite crucibles became rather acute, due both to the reduction in importation of foreign graphite and to the inability of crucible manufacturers to obtain certain clays which they had used and considered necessary.

In connection with work being done by the Bureau of Mines upon graphite crucibles, it was decided that more complete data than was available upon bond clays for use in graphite crucibles was necessary. Although considerable work has been done upon bond clays[2] and plastic fire clays with respect to their burning properties and their bonding strength when used with sand or clay-grog, practically no results are available from investigations in which graphite was the non-plastic material used. Bleininger's work upon bond clays is very valuable to the graphite crucible manufacturer in showing the temperature-structure relations of the clays.

The characteristic properties of graphite are decidedly different from those of sand or calcined grog. The graphite is infusible at clay-burning temperatures, although it burns readily in air at temperatures near or above 900° C. It thus precludes a reducing atmosphere in contact with the bonding clay.

The graphite may also have a mechanical effect upon the strength of the resultant body, unlike that produced by the more nearly spherical particles of fire-clay grog, in that the flakes always lie with the planes of their broad faces perpendicular to the line of pressure applied during molding. The graphite grains also have well defined cleavage planes along which they

[1] By permission of the Director, U. S. Bureau of Mines.

[2] Bleininger and Loomis, "The Properties of Some American Bond Clays," *Trans. Am. Ceram. Soc.*, **19**, 601 (1917).

are readily divided. The surfaces of the grains are not easily wet by water and the particles have somewhat the quality of oiled plates. These characteristics are not inherent in other non-plastics, such as sand or fire-clay grog, and would appear to have an injurious effect upon the strength of the finished body—due to the formation of laminations and to the poor adherence of the clay to the graphite surfaces. It is also noticeable that the clays when mixed with graphite are not as readily affected by heat as are the clays alone.

Since the graphite is quite unlike other non-plastics, it was thought advisable to determine some of the more important properties of bond clays when used with graphite alone. The clays for graphite crucibles may be classified, according to their use, into two classes: first, those suitable for brass-melting crucibles, and second, those suitable for steel-melting crucibles. Clays of the first class must burn fairly dense and develop good strength at or near 1100° C and should retain the same structure at the highest temperature used for brass melting, about 1250° C.[1] Clays of the second class must necessarily be more refractory than those of the first class—since crucibles for steel melting are used at temperatures ranging from 1400° to 1600° C. They must possess in this temperature range about the same qualities as those of the first class do between 1100° and 1250° C.

The crucible body must be dense enough at the pouring temperature of the metal to prevent penetration of slags and molten metal and to prevent oxidation of the graphite. However, to partly nullify the effect of strains set up by sudden heating and cooling of the crucible at every heat, the body should not be exceedingly dense. The graphite, however, tends to equalize the cooling strains and Seger[2] states that feldspar acts in the same direction. The high per cent of non-plastics used also decreases the effect of abrupt heat changes. Feldspar is also used in crucibles for brass melting to reduce the temperature at which the bodies become dense. Seger[3] found that Klingenberg clay,

[1] H. W. Gillet, "Brass Furnace Practices," Bureau of Mines, *Bulletin* **73**, 129.

[2] H. Seger, "Collected Writings," **2**, 1136.

[3] *Ibid.*

which has been largely used for crucibles, contained, in the crude state, about 6 per cent of feldspar. This is also confirmed by an analysis given by Bleininger.[1] The refractoriness of bodies used in crucibles for steel melting is often enhanced by the addition of plastic kaolin or sand, or both.

Investigation.

The clays tested were ground to pass a 20-mesh screen and mixed with an equivalent amount by weight of No. 1 grade Alabama graphite which had the following screen analysis through Tyler standard testing sieves:

	Per cent.
On 20-mesh	0.05
Through 20-mesh, on 35-mesh	7.55
Through 35-mesh, on 48-mesh	24.50
Through 48-mesh, on 65-mesh	48.72
Through 65-mesh, on 100-mesh	17.99
Through 100-mesh	1.14

The Alabama graphite had a specific gravity of 2.29 and an ash-content of 5.26 per cent.

Nineteen domestic, one English, and one German clay were tested. Some domestic clays were not included because they could not be obtained; some arrived too late; others were not tested because we were unable to ascertain the localities from whence they came. A few blended clays were offered for tests but as we were unable to learn the identity of the individual clays which made up the blends, the tests would not have had much value and were not made.

The tests made covered water of plasticity, resistance to slaking, ratio of pore to shrinkage water, ratio of pore water to true volume of the body constituents, a classification of the clays as to working qualities when used with graphite, dry and burned transverse strength, the degree in which the clay aids in resistance to oxidation of the graphite, loss in strength from sudden cooling, and the softening points of the clays alone.

[1] "Notes on the Crucible Situation," read before the Institute of Metals, Boston, Mass., Sep 25, 1917.

Clays Used.—The following were the clays tested, the numbers assigned to them in the investigation, and the dealers from whom they were obtained:

No. 3.01 From Laclede-Christy Clay Products Co., St. Louis, Mo.
No. 3.02 From Laclede-Christy Clay Products Co., St. Louis, Mo.
No. 3.03 From J. T. Bramlett, Enid, Miss.
No. 3.04 From J. T. Bramlett, Enid, Miss. (from property of Southern Ball Clay Co.)
No. 3.05 From McClendon Clay Co., Senatobis, Miss.
No. 3.06 From F. E. Bausch, St. Louis, Mo.
No. 3.07 From F. E. Bausch, St. Louis, Mo.
No. 3.08 From F. E. Bausch, St. Louis, Mo.
No. 3.09 From F. E. Bausch, St. Louis, Mo.
No. 3.10 From Harbison-Walker Refractories Co., Pittsburgh, Pa.
No. 3.11 From Harbison-Walker Refractories Co., Pittsburgh, Pa.
No. 3.12 From Harbison-Walker Refractories Co., Pittsburgh, Pa.
No. 3.13 From Highlands Fire Clay Co., St. Louis, Mo.
No. 3.14 From J. T. Bramlett, Enid, Miss.
No. 3.15 From Mandle Clay Mining Co., Porters, Tenn.
No. 3.16 From Kentucky Cons. & Improvement Co., Mayfield, Ky.
No. 3.17 From Kentucky Cons. & Improvement Co., Mayfield, Ky.
No. 3.18 From Kentucky Cons. & Improvement Co., Mayfield, Ky.
No. 3.19 From Mandle Clay Mining Co., Whitlock, Tenn.
No. 3.20 Dorset English ball clay from John Sant & Sons Co., E. Liverpool, Ohio.
No. 3.22 Klingenberg crucible clay from Jos. Dixon Crucible Co., Jersey City, N. J.

Preparation.—The clays were mixed dry with the graphite, water added to the best working consistency as determined by feel, pugged thoroughly by hand, wrapped in a damp cloth and laid away in a covered jar for two days, after which they were taken out, re-pugged and molded.

Two one-inch cubes for the slaking test were made from each mix together with a sufficient number of bars, $1/2'' \times 1''$ in cross section, for transverse strength determinations. Cylindrical oxidation trials $4''$ long by $2''$ in diameter with semi-spherical ends were also made. In molding the pieces, bars somewhat narrower and deeper than the mold were cut from the plastic mass with a wire-bow, placed in the mold and pressed down by hand, smoothed off with a spatula, and numbered.

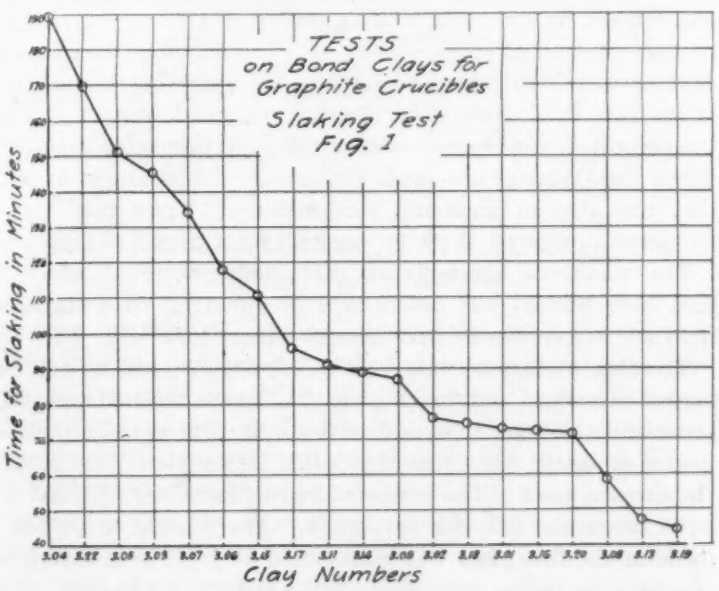
All of the pieces were dried for two days under a cloth, the cloth

being then removed and the bars dried for several days at room temperature, then for two days at 70° C, and finally for 24 hours or longer at 110° C.

The wet weights and wet volumes of three bars were determined immediately after molding. The dry weights and dry volumes of the same three bars were determined after the final drying at 110° C. The water of plasticity was expressed in the per cent loss in weight in terms of the dry weight. As a rule, the more plastic clays required a higher proportion of tempering water than did the lean ones.

The wet and dry volumes were determined in a volumeter of the pycnometer type as described by Schurecht.[1] The drying shrinkage was expressed as the per cent loss in volume in terms of the dry volume of the bar.

The rate of slaking was taken as the time, in minutes, for disintegration in water of a one-inch cube previously dried at 110° C. The result taken in each case was the average of two determinations. (See Table 2 and Fig. 1.)



[1] *J. Am. Ceram. Soc.*, 1, 556 (1918).

The very plastic clays dried to dense horn-like bodies and required longer periods for disintegration than did the lean clays which gave more porous and friable bodies. The test, however, is subject to considerable error on account of the large number of factors which cannot be closely guarded. It serves only in differentiating between clays of widely divergent bonding properties.

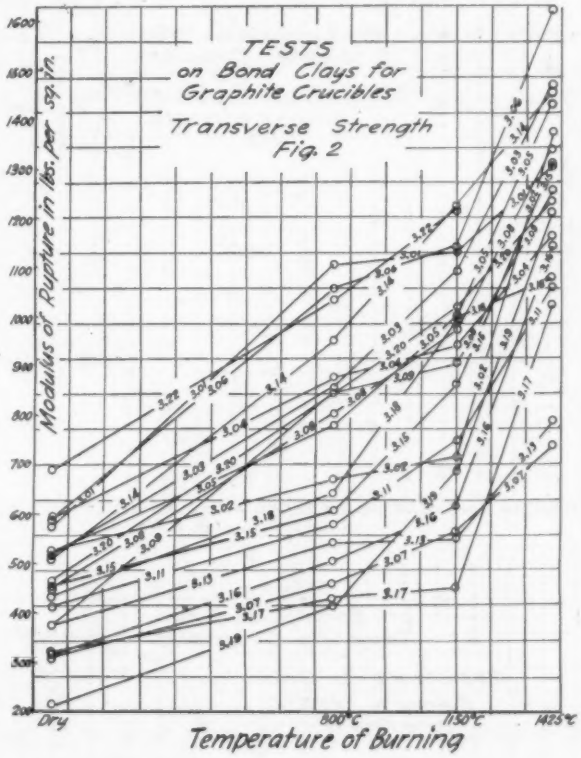
The dry transverse strength was taken as the modulus of rupture in pounds per square inch. Bars $^1/_2'' \times 1''$ in cross section were broken on a five-inch span by a uniformly increased load applied at a point equidistant from the bar supports. The dimensions at the break were measured to the nearest $^1/_{100}''$ by means of an Ames dial. The moduli were then calculated from the modulus of rupture formula. The results given (Fig. 2) are the average of fifteen determinations in each case.

Burning.—Bars for burned transverse strength, bars for the determination of loss in strength from sudden cooling, and the oxidation trials were embedded in graphite in covered saggers and burned in horizontal draft gas-fired test kilns. A sufficient number of bars of each mixture to cover all requirements were fired in individual burns to each of the following temperatures at the rate of 40° per hour: 800°, 1150°, and 1425° C. These temperatures correspond, respectively, to the temperatures at which the crucibles are fired, and to the temperatures at which they are used in brass and steel-melting. Upon reaching the temperature desired, the kiln was held for a period of four hours.

The transverse strength for each temperature at which the bars were burned was determined by breaking on a three-inch span and is expressed in pounds per square inch (Fig. 2).

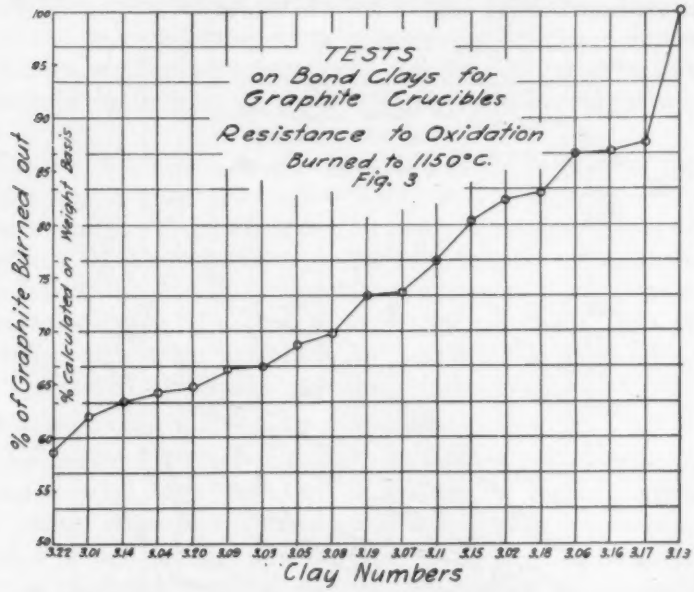
The four oxidation trials from each mixture—two having been burned to 1150° and two to 1425° C—were weighed and placed about one-inch apart in a gas-fired test kiln. The pieces were so supported on knife edges that they could be completely encircled by the furnace gases. The temperature was increased to 1100° C in $13^1/_2$ hours and held for two hours. The content of carbon dioxide in the flue gases was maintained at 7 per cent throughout the burn by means of a Simmance-Abady CO_2 recorder. Upon cooling, each piece was again weighed, sawed at right angles to

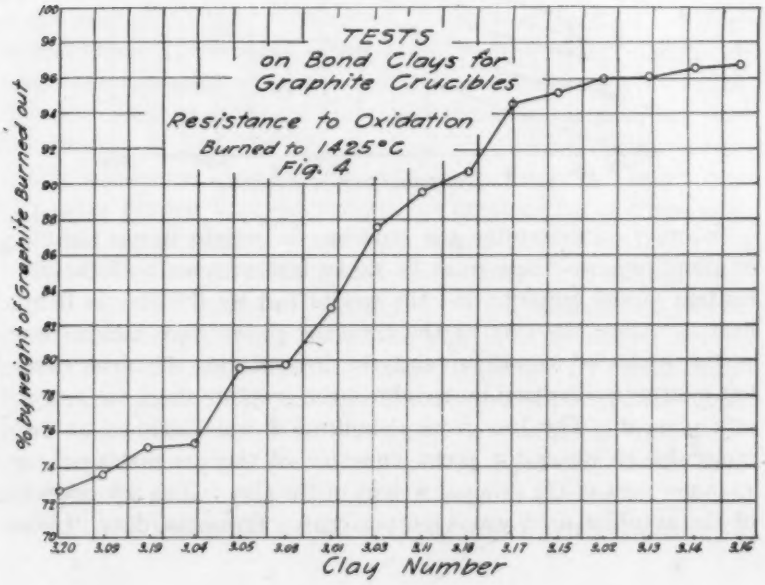
the longer axis, and both the unoxidized area and the area of the whole piece measured with a planimeter. The oxidized area was expressed in per cent of the whole area.



In order to determine the true loss in weight in per cent of graphite present, there must be taken into account both the ash-content of the graphite and the weight lost by the clay in dehydrating—since the clay at the time the pieces were molded was in the hydrated condition and the loss of the chemical water left a larger proportion by weight of the graphite than was originally present. The loss from dehydration was assumed at two molecules of water for every molecule of clay as first used, or 13.9 per cent of the original weight of the clay. The ash-content of the graphite used was 5.26 per cent. From the data, it was

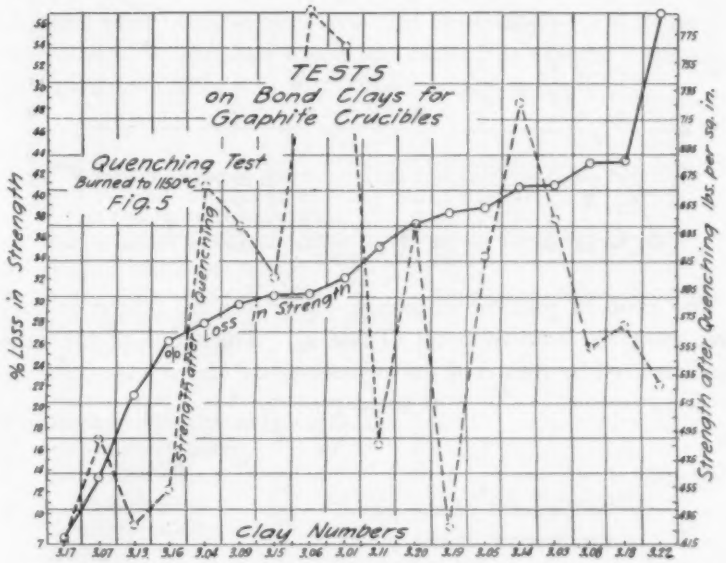
then possible to calculate the per cent of the graphite oxidized in terms of the graphite originally present (Figs. 3 and 4).





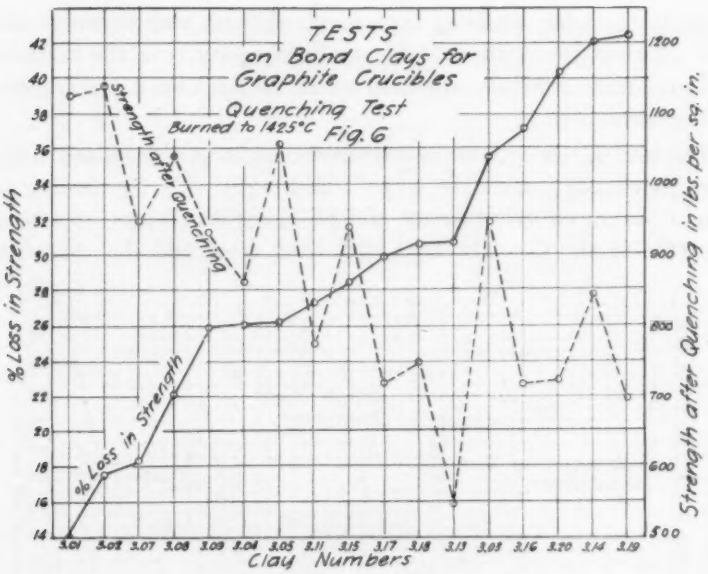
Oxidation trials such as were used, with no sharp corners, insure an even penetration of the oxidizing gases over the surfaces and give more reliable data than would be the case if rectangular pieces were used.

The loss in strength from sudden cooling was determined upon bars previously burned to 1150° and 1425° C, by heating to 800° C in an electric furnace and plunging into water at a temperature of 18° C. The bars were then dried and the operation



repeated until they had been quenched five times. The moduli of rupture of the bars were then determined by breaking on a three-inch span as before and the per cent loss in strength in terms of the original strength was calculated from the available data. The results (Figs. 5 and 6) are the averages of at least 12 determinations in each case.

The softening points of cones made from the individual clays were compared to those of standard cones in a gas-fired pot furnace, and were expressed in terms of the latter cones (Table 3).


TESTS
on Bond Clays for
Graphite Crucibles
Quenching Test
Burned to 1425°C Fig. 6
% Loss in Strength
Strength after Quenching in lbs. per sq. in.
Clay Numbers
3.01 3.02 3.07 3.08 3.09 3.04 3.05 3.11 3.15 3.17 3.18 3.13 3.03 3.16 3.20 3.14 3.19

The ratio of pore to shrinkage water was calculated in each case from the data at hand (Table 2). The value of the ratio was obtained by means of the expression

$$\frac{W - D}{Vw - Vd} - 1$$

where

W = wet weight of the piece.
D = dry weight of the piece.
Vw = wet volume of the piece.
Vd = dry volume of the piece.

The ratio of pore volume to the true volume of the bar constituents is more important and the volume of the ratio may be obtained by the expression

$$\frac{(W - D) - (Vw - Vd)}{\frac{D}{S}}$$

where

W = wet weight of the bar.
D = dry weight of the bar.

Vw = wet volume of the bar.
Vd = dry volume of the bar.
S = true specific gravity of the bar.

The specific gravity of each clay was taken as 2.6 and the specific gravity of the graphite used was found to be 2.29, so that S in the above expression has a value of 2.445.

To determine the order in which the clays might be classed as regards working qualities, 500 grams of a 1 : 1 clay and graphite mixture was made up from each clay, tempered and pugged by the same man in each case, and aged and classified by four men individually. The clays were then classed as seemed most consistent with the results. (See Tables 1, 2, 3 and 4.)

TABLE 1.

Clays arranged in the order of their working qualities.[1]

3.08	Warps considerably in drying.	Very good working qualities.
3.03	Warps considerably in drying.	
3.22	Warps considerably in drying.	
3.20	Warps considerably in drying.	
3.06	Bars dry straight, but have peculiar wrinkled surfaces.	
3.04	Warps considerably in drying.	
3.09	Warps considerably in drying.	Good working qualities.
3.19	Dries fairly straight.	
3.14	Warps somewhat.	
3.01	Warps somewhat.	
3.05	Warps somewhat.	
3.18	Dries well.	
3.15	Warps only a small amount.	
3.16	Dries well.	Rather poor working qualities.
3.07	Dries well.	
3.11	Warps very little.	
3.02	Warps very little.	
3.13	Dries well.	
3.17	Warps very little.	
3.10	Dries well.	Too lean for molding.
3.12	Dries well.	

[1] No trouble from cracking was experienced with any of the clays.

TABLE 2.

No.	Water of plasticity.	Drying shrinkage in terms dry-bar volume.	Ratio, pore to shrinkage water.	Ratio, pore to true volume of the bar.	Time for slaking, in minutes.
3.01	28.31	22.59	1.117	36.5	73
3.02	36.85	22.72	1.709	56.2	76
3.03	29.34	21.32	1.24	39.8	146
3.04	27.75	22.31	1.120	35.9	190
3.05	27.73	21.48	1.168	36.5	151½
3.06	29.48	20.66	1.318	41.1	118
3.07	27.88	15.89	1.885	45.5	134½
3.08	33.42	29.68	0.845	37.4	58½
3.09	34.48	25.57	1.208	46.1	87
3.11	28.65	30.12	1.198	46.65	91½
3.13	25.56	23.91	0.867	28.9	47½
3.14	26.17	18.98	1.360	36.9	89
3.15	35.97	24.71	1.298	49.9	111
3.16	28.56	15.39	1.955	46.4	72½
3.17	29.18	19.71	1.383	41.35	96
3.18	34.08	24.10	1.200	45.4	74½
3.19	27.95	18.64	1.438	40.35	44½
3.20	31.17	23.38	1.178	40.64	71½
3.22	32.02	29.54	0.879	39.16	170

Discussion of Results.

It is evident that no clay satisfies, to a high degree, all requirements for graphite crucible use. In fact, some of the necessary qualities are so diametrically opposite as to insure no one clay being entirely satisfactory. Some of the clays of course rank higher than others as regards all requisite properties and by choosing one of these as the basis and blending others with it, a mixture may be built up which should give more satisfactory results than could be obtained by the use of any single clay.

By a comparison of the data herein given with that given by Bleininger,[1] upon the strength of 1:1 mixtures of bond clay and sand, it may be seen that the average strength of bodies in which graphite is used is considerably higher than that of those in which sand is used. This is probably due to the difference in

[1] *Trans. Am.Ceram. Soc.*, **19**, 601 (1917).

TABLE 3.

No.	Dry strength.	Strength after burning at 800° C.	Strength after burning at 1150° C.	Strength after burning at 1425° C.	Strength after burning at 1150° C and quenching 5 times.	Strength after burning at 1425° C and quenching 5 times.	Per cent loss in strength after burning at 1150° C and quenching.	Per cent loss in strength after burning at 1425° C and quenching.	Softening point in standard cones.
3.01	576.4	1104.11	1131.9	1308.8	768.31	1125.1	32.1	14.0	31
3.02	525.3	671.55	719.2	1378.8	...	1137.0	...	17.5	23
3.03	516.6	857.2	1092.0	1470.4	646.2	948.6	40.85	35.6	31
3.04	590.6	878.1	946.5	1165.5	682.6	861.9	27.9	26.1	30 1/4
3.05	518.3	781.4	1008.9	1433.6	617.8	1058.7	38.8	26.2	30
3.06	595.8	1058.8	1142.4	1618.8	793.1	....	30.6	....	30 1/2
3.07	312.1	460.21	564.6	734.0	489.1	599.5	13.35	18.35	32 1/2
3.08	449.2	804.1	972.1	1339.8	554.8	1043.4	42.9	22.1	30 1/4
3.09	378.0	848.45	910.9	1259.1	640.9	933.9	29.62	25.9	32 1/2
3.11	416.2	580.5	750.7	1065.7	486.8	775.2	35.1	27.3	31
3.13	372.1	542.4	549.2	789.9	429.7	547.0	21.8	30.7	31
3.14	510.9	956.3	1226.1	1459.5	727.7	845.7	40.65	42.1	30 1/2
3.15	453.8	611.3	868.9	1315.3	603.7	940.5	30.5	28.5	32 1/4
3.16	313.8	506.6	619.8	1143.5	457.6	718.0	26.2	37.2	30 1/4
3.17	314.7	432.1	451.1	1026.9	416.5	719.3	7.7	29.9	30
3.18	431.9	644.0	1000.7	1080.0	569.9	749.6	43.1	30.6	33
3.19	214.1	414.8	687.1	1212.0	423.4	698.2	38.3	42.4	32 1/2
3.20	464.5	846.0	1020.0	1234.5	640.1	724.8	37.2	41.3	33
3.22	691.7	1035.1	1219.5	....	526.4	....	56.8	...	31 1/2

TABLE 4.

Oxidation trials burned at 1150° C. Oxidized for 10 hrs. at 1100° C.				Oxidation trials burned at 1425° C. Oxidized for 10 hrs. at 1100° C.		
No.	Per cent of whole area oxidized.	Per cent loss in weight.	Per cent graphite burned out.	Per cent of whole area oxidized.	Per cent loss in weight.	Per cent of graphite burned out.
3.01	94.40	31.53	62.0	70.14	42.2	83.0
3.02	71.59	41.97	82.4	95.01	48.53	96.0
3.03	46.53	33.29	66.6	56.03	44.74	87.6
3.04	47.59	32.76	64.25	62.19	38.37	75.35
3.05	52.65	34.65	68.1	74.76	40.54	79.60
3.06	56.12	43.88	86.6	broken	broken	
3.07	62.93	37.26	73.60	broken	broken	
3.08	76.15	35.29	69.9	67.96	40.55	79.75
3.09	49.60	33.81	66.4	58.34	37.42	73.60
3.11	60.71	39.07	76.62	81.57	45.58	89.6
3.13	96.13	50.91	100.01	97.86	48.88	96.1
3.14	51.67	32.50	63.3	71.87	49.14	96.6
3.15	67.85	41.01	80.4	86.76	48.58	95.2
3.16	87.46	44.15	86.8	96.49	49.48	96.8
3.17	78.32	44.66	87.7	93.99	48.17	94.6
3.18	70.53	42.23	83.0	75.76	46.21	90.75
3.19	54.75	37.36	73.35	65.50	38.31	75.1
3.20	53.43	32.93	64.7	50.0	36.96	72.6
3.22	40.94	29.86	58.7	...	...	...

the shape of the grains. Similar results were obtained in laboratory tests to determine the effect of grain-size and shape upon the dry and burned strength of clay-graphite mixtures. It was found that the angular grains of Ceylon graphite, and the thick grains produced by coking Alabama graphite, gave bodies of lower strength than did the thin flakes of the untreated Alabama graphite.

An attempt was made to determine the strength, at furnace temperatures, of bars made from the clay-graphite mixtures but the bars were oxidized to such an extent, even under as reducing an atmosphere as could be maintained, that this part of the investigation had to be postponed pending the discovery of a suitable protective coating for use on the trial pieces to prevent oxidation.

Accurate data upon the hot strength of crucible mixtures would be very valuable—since the crucibles while at furnace temperatures are subjected to a high internal pressure from the molten metal.

The porosity-temperature and volume shrinkage-temperature relations of the mixtures were also determined but such small changes occurred over comparatively large temperature intervals, that sufficiently accurate data was not obtained from the number of trials employed. This part of the investigation is now being repeated. The data obtained, however, indicates that the refractoriness of the clay is increased by the addition of graphite.

The porosity-temperature relation is very peculiar. In the preliminary laboratory work it was found that the porosities of clay-graphite bodies burned to cone 15 were greater by about 3 per cent of the dry volume than were the dry porosities. From the oxidation curves it may also be seen that the bodies burned to 1425° C were less resistant to oxidation of the graphite than were those burned at 1150° C. This would indicate greater porosity at the higher temperature than at 1150° C. Such an increase in porosity is contrary to the general behavior of clays. even at their over-burning temperatures, as may be seen by consulting the data given by Fulton and Montgomery[1] or by Bleininger.[2]

By a consultation of the data given in Table 3, it may be seen that several of the mixtures after being burned at 1425° C showed a lower proportional decrease in strength from quenching than they did when burned at 1150° C. This may also be due in part to the greater porosity of the bodies burned to the higher temperature.

The peculiar influence of the graphite upon the body may be due to changes occurring within the graphite itself.

It is possible that, since graphites were probably formed under conditions of extreme heat and pressure, an increase in volume occurs upon being heated to a high temperature at atmospheric pressure The volume increase would tend to disrupt the grains

[1] *Trans. Am. Ceram. Soc.*, **17**, 409 (1915).

[2] *Loc. cit.*

along their cleavage planes and so open up the body to some extent.

MINING EXPERIMENT STATION,
BUREAU OF MINES,
COLUMBUS, OHIO.

COMMUNICATED DISCUSSION.

M. G. BABCOCK: The results which we have obtained at this laboratory in our investigations of clays suitable for bonding graphite for crucibles check those obtained by Mr. Booze. That is, we have found Laclede-Christy B-291, or No. 3.01 in Mr. Booze's paper, to be one of the best single bond clays considering all the data so far available. The English Dorset ball clay is also a good single clay. The writer knows of one manufacturer who had excellent results with this clay as a substitute for the Klingenberg clay.

In laboratory experiments on bond clays, the writer has secured results checking Mr. Booze's statement "that the more plastic clays require a higher proportion of tempering water than do the lean ones." Also, the writer has noted that the slaking test is subject to error and for clays having similar plasticity gives very little differentiation.

The point mentioned by Mr. Booze in his concluding paragraph regarding a blended mixture of clays to substitute for a single clay, is one that merits attention. At the present time, the writer has under investigation a series of blended clays using clay 3.01, or B-291, as a basis together with two Enid clays. The investigation has not been carried to a point where comparative data can be submitted. It is anticipated that from this series a mixed bond clay will be found that will have properties better than any single clay so far reported.

The writer hopes that the results of Mr. Booze's work will be carried further by making actual factory-size crucibles and using the same under standard foundry practice. In this way the Society would have the benefit of a technical investigation applied to an industrial problem and under conditions far different from those existing in the laboratory. This, however, would cover a long period of time but the data obtained should justify the expenditure to this end. Mr. Booze is to be congratulated for this piece of work and the Society is indeed fortunate to have it on record.

MELLON INSTITUTE OF INDUSTRIAL RESEARCH,
PITTSBURGH, PA.

NOTE ON THE USE OF MAGNESIA AS AN OPACIFIER.

By V. S. Schory, Tiffin, Ohio.

Introduction.

In connection with a rather extended investigation for the purpose of producing a satisfactory glaze for one-fire ware, it was found convenient to make a brief study of the opacifying properties of magnesia in high-fire glazes. In a number of cases the writer had observed mixtures containing considerable amounts of magnesia which fired to opaque enamel-like coats with good gloss. Mention is made in the Transactions[1] of the use of magnesia as an opacifier in stoneware glazes at cone 7. When the first attempts were made to secure similar effects in porcelain glazes at from cones 9 to 11, the results were not uniform. In some cases the resulting coat was a good opaque white; again, with no great change in temperature or glaze composition, the glaze would be transparent and of a dirty, greenish yellow cast. Some of the first indications were to the effect that the addition of small amounts of barium and zinc resulted in increased transparency.

Experimental.

In order to prove or disprove these indications, and to secure sufficient definite data to explain the erratic results which had been obtained, the following brief study was outlined. The work was made systematic within the limits of heat treatment available in the kilns used in regular factory practice. The following glazes were prepared:

No. 1.	No. 2.	No. 3.		
0.30	0.30	0.30 K_2O		
0.20	0.30	0.40 CaO	0.50 Al_2O_3	4.00 SiO_2
0.20	0.10	0.00 ZnO		
0.30	0.30	0.30 MgO		

[1] R. T. Stull, *Trans. Am. Ceram. Soc.*, 11, 605 (1909).

No. 4.	No. 5.	No. 6.			
0.25	0.25	0.25	K_2O		
0.25	0.35	0.45	CaO		
0.20	0.10	0.00	ZnO	0.40 Al_2O_3	3.30 SiO_2
0.30	0.30	0.30	MgO		

No. 7.			
0.30	K_2O		
0.70	CaO	0.50 Al_2O_3	4.00 SiO_2

Glaze No. 1 is a duplicate of an opaque glaze given by Stull in the Transactions.[1] Glaze No. 7 corresponds to the formula of cone 4 and was prepared for comparison with the other members.

The glaze slips were concentrated to the plastic state and formed into briquettes. The dried briquettes were fired in commercial kilns to cones 5, 7, 9 and 12.

Results.

Glaze No. 1.—At cone 5 this mixture was an over-fired porcelain but the briquettes were not badly deformed. The surfaces had a fairly good gloss. The fracture of the pieces was stony. The color was a fairly good white.

At cone 7 the briquettes had softened sufficiently to lose shape and flatten out considerably. The surface gloss was inferior to that at cone 5. The fracture was less stony and more glassy than at cone 5 but showed no marked development of vesicular structure. The color was not quite so white as at cone 5.

At cone 12 the briquettes had fused down to form level lakes of glass, having better gloss than at any of the lower temperatures. The fracture was glassy. Throughout the mass were innumerable small bubbles. The color had become yellowish and was much inferior to the color at cone 9. Apparently, the glass had lost its opacity except that due to the bubbles present. When applied as a glaze coating no opacity was noticeable.

Glazes Nos. 2 to 6.—Briquettes of glazes Nos. 2 to 6, fired to the same temperatures, formed series similar to that of glaze No. 1. Briquettes of glazes Nos. 1 and 4 developed gloss at cone 5, becoming inferior at cones 7 and 9. The other numbers developed gloss by cone 7, becoming inferior at cone 9. At cone

[1] *Loc. cit.*, p. 612.

12 all members were fused to lakes of glass with better gloss than at any of the lower temperatures.

No considerable development of vesicular structure was observed in any glaze at cone 9, but at cone 12 innumerable small bubbles occurred throughout the mass in every case. In glazes Nos. 4, 5 and 6 the bubbles were larger than in glazes Nos. 1, 2 and 3.

Each mixture was a good white at the stage where it was a porcelain sufficiently overfired to develop good gloss. With increased heat treatment and softening of the briquettes there was a corresponding loss of color. At cone 12 all had become yellowish.

The loss of opacity was approximately concurrent with the development of the yellowish color. The more fusible members were only partially opaque at cone 9 and at cone 12 no opacity was evident in any of the fusions except that due to the bubbles present.

Glaze No. 7.—Briquettes of glaze No. 7 were porcelains slightly overfired at cone 5 and with glossy surfaces and rounded corners at cone 7. At cone 9 the briquettes had lost shape and were much inferior in color and opacity to the members containing magnesia. At cone 12, glaze No. 7 was similar to glazes Nos. 1, 2 and 3.

The effects of magnesia as noted in glaze No. 3 were the maintenance of good color and opacity to a higher temperature than obtained in the case of glaze No. 7. The difference between glazes No. 3 and 7 were not so marked at cones 5 and 7, but at cone 9 glaze No. 3 was much the superior in color and opacity. The action of zinc was primarily to promote early fusion. It had no marked effect on color in these glazes.

Comparison with Commercial Glazes.

For further comparison with these mixtures, briquettes were made from two commercial glazes, a stoneware glaze maturing at cone 8 and a porcelain glaze maturing at cone 10. At cone 5 the briquette of stoneware glaze had fused down to a viscous fluid state and showed incipient vesicular structure. The surface was dull. At cone 7 the fluidity, vesicular structure and gloss had increased. At cone 9 the mass had lost opacity and contained many bubbles. When applied as a glaze coating and

fired to cone 8 the glaze was bright but retained some small bubbles.

Briquettes of the porcelain glaze fused down to a viscous fluid state with some vesicular structure at cone 5. The surface gloss was fairly good at cone 5 and improved with increase in heat treatment to cones 7 and 9. At cone 9 the fusions contained a number of rather large bubbles. When applied to ware in the usual manner this glaze cleared satisfactorily at cone 9.

It was noted that glaze No. 1, for example, lost gloss from cone 5 to cone 7, but that the stoneware glaze, though more fusible, was dull at cone 5 and developed better gloss with increase in heat treatment. The porcelain glaze at cone 5 developed gloss which improved at higher temperatures.

Conclusions.

From the data it appears that glazes Nos. 1 to 6, when fired to form opaque, glossy coats, are really in the condition of over-fired porcelains and may be more accurately designated as glossy, vitreous slips. It was found also that zinc and barium did not increase the transparency of the coats except as they increased the fusibility.

DIRECT VOLUME-DETERMINATION IN A VOLUMETER OF THE PYCNOMETER TYPE.

By J. B. Shaw.

In a recent article, H. G. Schurecht[1] illustrates a pycnometer which he has used in measuring the volumes of clay test pieces. He offers considerable criticism, which is certainly somewhat justified, of the Seger volumeter, because of its complex construction, fragility, inaccuracy, and slow operation. There is a real need for some simpler type of volumeter and as the writer has been using one similar to that illustrated by Schurecht, but differing in one essential, it was deemed worth while to give a description at this time.

The volumeter (Fig. 1) does not differ materially from Schurecht's in general dimensions; in fact, it was purposely made to conform with his since the size shown is very adaptable for ceramic work. The volumeter differs essentially from the pycnometer in the size of the orifice in the glass stopper. The tube in the stopper in this volumeter has an internal diameter of $1/4''$ so as to permit the liquid to flow into the bottle from a burette.

Following is the procedure in measuring the volume of a briquette:

(1) Saturate the briquette with liquid (kerosene if green, water if burned).

(2) Place the briquette in the volumeter.

(3) Fill the volumeter to the mark.

(4) Remove stopper and briquette.

(5) Replace stopper in same position as original.

(6) Run liquid from the burette through the tube in stopper until the bottle is filled to the mark.

(7) Read the volume directly from burette.

Schurecht's claim to accuracy must be admitted. His claim to speed and cheapness are doubted. One who makes two weighings, accurate to 0.01 or 0.05 g., and four mathematical calcula-

[1] *J. Am. Ceram. Soc.*, 1, 556 (1918).

tions, each involving four figures, in two minutes, will work more rapidly than the average man and probably too fast for accuracy. For weighing pieces of 300 to 400 grams mass, a balance sensitive to 0.01 g. is more costly than a Seger volumeter. There is no desire on the part of the writer to detract in any way from the real merits of a volumeter of the pycnometer type; it is recognized as having many points in its favor and is certainly to be preferred to the Seger volumeter. Its use, however, seems to involve refinements not required in making other tests on the same kind of test pieces.

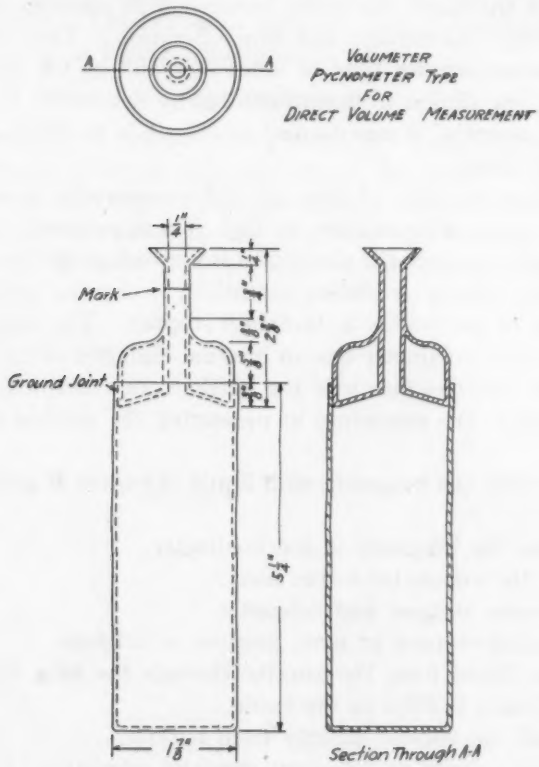


FIG. 1.

The volumeter illustrated required only a burette in addition to the pycnometer in making volume determinations. The

burette can be read accurately to 0.1 cc. and estimated to 0.05 cc.

The experimental error in manipulating this apparatus will approximate about 0.1 cc., which in the average determination would represent an error of about 0.30 per cent. It is doubtful if greater accuracy is required in work of this kind.

As the Standards Committee of the American Ceramic Society has recommended that briquettes be weighed accurately to 0.1 g., it would be useless to attempt to measure volumes to a greater degree of accuracy.

The chief points of merit claimed for this volumeter are: (1) speed, (2) simplicity, (3) low cost, (4) sufficient accuracy.

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COMMUNICATED DISCUSSIONS.

H. G. SCHURECHT: Mr. Shaw states in his paper that it is impossible to determine the volume of a briquette in 2 minutes with the pycnometer-volumeter described by me in this JOURNAL.[1] When the weighings and calculations are made in the customary manner, Mr. Shaw's assumption is correct, but by making the balance read automatically for fractional gram intervals, and by using tables for volume calculations, such determinations were made in the Bureau of Mines laboratories in an average of one and one-half minutes, when weighing a large number of test pieces. These methods were as follows:

Making the Balance Read Automatically.—This may be done with most chemical balances in the manner shown in Fig. 2. By attaching a weight (an ordinary screw pinchcock may be used) to the needle indicator, the moment W $\times$ A becomes greater. This may be so adjusted by moving the weight up or down on the needle, so that when the needle is 10 major divisions to the right or left of the zero point, it may be brought to zero by adding a one-gram weight to the opposite pan. This makes each intermediate division read 0.1 gram and with the balance as used the weight could easily be estimated to 0.025 gram by noting the position of the indicator. Hence, it is only necessary

[1] *J. Am. Ceram. Soc.*, 1, 556 (1918).

to place a weight, within one gram of that of the briquette, on the pan and the weight above or below that of the briquette may be read automatically, thus saving the time otherwise necessary in handling the smaller weights. For example: if a briquette weighs 40.75 grams, place the briquette on left pan, a 40-gram weight on the right pan, release the balance slowly (thus preventing vibrations of the needle) and the needle will come to rest at 7.5 divisions to the right of center.

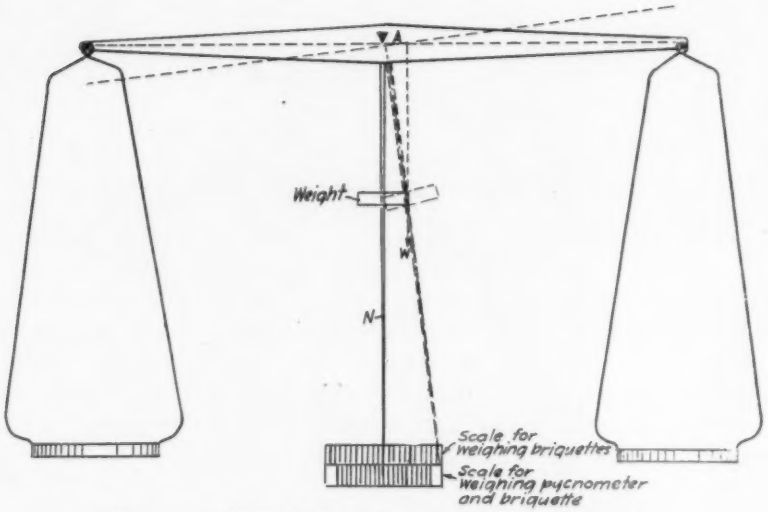

FIG. 2.—Balance with automatic weighing attachment.

It was found that for heavier weights, above 100 grams, as is necessary when weighing the pycnometer-volumeter, the indicator did not swing quite as far to the right or left upon the addition of a gram weight, this probably being due to the increased friction caused by increased weight. It was therefore necessary to use another scale, calibrated for use with the pycnometer, which was pasted to the lower half of the original scale (see Fig. 2). Where the briquettes are about the same size, the time of weighing is reduced about $66^2/_3$ per cent by using the automatic attachment.

Obtaining Volumes from Tables.—The calculations involved

for determining the volume with a pycnometer-volumeter are as follows:

$$V = \frac{W - W_1 + B}{S} = W - \frac{(W_1 - B)}{S} \text{ in which}$$

V = volume in cc.
W = weight of pycnometer plus liquid.
W_1 = weight of pycnometer plus liquid plus briquette.
B = weight of saturated briquette.
S = specific gravity of liquid.

The first step is to obtain $W_1 - B$, then $W - (W_1 - B)$, and finally

$$W - \frac{(W_1 - B)}{S} = V.$$

In preparing the tables it is necessary to obtain sufficient data to cover the upper and lower limits of these values, which vary with the size of briquette and size of volumeter. The following pre-calculated tables may then be prepared, varying the small variable from left to right and the large variable from top to bottom as indicated. For example:

$B = 44.85$
$W_1 = 142.85$
$W_1 = 168.50$
$S = 0.816$

To determine $(W_1 - B)$, run down the left hand column of Table 1 to 44.85 and then follow this line to the right until under 168.50, which gives the pre-calculated difference, 123.65. Since the values for W_1 varied over a comparatively large range of numbers it was found impossible to arrange all of the data on one table so they were separated into a number of tables which were bound together and indexed on the right hand side. For example: one table contains all numbers between 168.00 – 168.95, the next 169.00 –169.95, etc.

With 123.65 and 142.85 (W_1), the value $W - (W_1 - B)$ is obtained in a similar manner from Table 2 and found to be 19.20.

With 19.20 and 0.816 (S), the value of V is then obtained from Table 3 and found to be 23.53.

When determining the volumes of a large number of test pieces which are approximately the same size, as is generally the case when testing clays, the use of the automatic weighing attachment and tables for determining volumes is recommended because of the time saved, since the accuracy in weighing is far below that of the other experimental errors.

TABLE 1.—To determine ($W_1 - B$).

	W_1. →							
	168.00	168.05	168.30	186.35	168.40	168.40	168.50	168.55
44.60	123.40	123.45	123.70	123.75	123.80	123.85	123.90	123.95
.65	.35	.40	.65	.70	.75	.80	.85	.90
.70	.30	.35	.60	.65	.70	.75	.80	.85
.75	.25	.30	.55	.60	.65	.70	.75	.80
.80	.20	.25	.50	.55	.60	.65	.70	.75
.85	.15	.20	.45	.50	.55	.60	.65	.70
↑ .90	.10	.15	.40	.45	.50	.55	.60	.65
.95	.05	.10	.35	.40	.45	.50	.55	.60
B 45.00	.00	.05	.30	.35	.40	.45	.50	.55

TABLE 2.—To determine $W - (W_1 - B)$.

	W. →							
	142.60	142.65	142.70	142.75	142.80	142.85	142.90	142.95
123.50	19.10	19.15	19.20	19.25	19.30	19.35	19.40	.45
.55	.05	.10	.15	.20	.25	.30	.35	.40
.60	.00	.05	.10	.15	.20	.25	.30	.35
.65	18.95	.00	.05	.10	.15	.20	.25	.30
↑ .70	.90	18.95	.00	.05	.10	.15	.20	.25
.85	.85	.90	18.95	.00	.05	.10	.15	.20
.80	.80	.85	.90	18.95	.00	.05	.10	.15
.85	.75	.80	.85	.90	18.95	.00	.05	.10
.90	.70	.75	.80	.85	.90	18.95	.00	.05
(W_1 — B) .95	.65	.70	.75	.80	.85	.90	18.95	.00

TABLE 3.

To determine $\frac{W - (W_1 - B)}{S} = V$.

W − (W₁ − B) ↑	S. → 0.814	0.815	0.816	0.817	0.818	0.819
		23.00				23.20
19.00	23.34	23.31	23.28	23.26	23.23	23.20
.05	.40	.37	.34	.32	.29	.26
.00	.46	.43	.40	.38	.35	.32
.15	.52	.49	.46	.44	.41	.38
.20	.60	.56	.53	.51	.47	.44
.25	.65	.62	.59	.57	.54	.51
.30	.71	.68	.65	.63		
.35	.77	.74	.71			
.40	.83	.80	.76			
.45	.89	.86	.83			

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J. B. SHAW: There seems little doubt that by the use of the tables illustrated by Mr. Schurecht the time of making volume determinations in the pycnometer-volumeter would be very materially reduced. It seems obvious, however, that the method of reading volumes direct is bound to require less time than any method requiring weighing—regardless of how many short-cuts are used.

It is doubtful if the slightly higher degree of accuracy obtained by the use of this elaborate set of tables and expensive balances will justify their use in the average ceramic laboratory. Where great accuracy is desired, this method is probably the best yet devised, but for ordinary purposes the volumeter, reading volumes directly, is sufficiently accurate and certainly decidedly cheaper.

AN AMERICAN PORCELAIN CONTAINING NO FREE SILICA.

By Arthur S. Watts.

The following is one of a series of studies conducted with the object of producing a practical porcelain body which is free from the faults due to the presence of free silica. The chief of these faults is supersensitiveness to sudden change of temperature. Second only to this fault is the tendency to excessive warping The mode of procedure in this study was as follows:

A standard porcelain body was separated into its two essentials: (*a*) plastics, including all clays, and (*b*) non-plastics, including all feldspar, whiting, and flint. The non-plastic portion was calcined at a temperature just sufficient to produce a pyrochemical action between the feldspar and whiting and to allow them to act on the flint. Such a calcine, however, must not reach the glossy stage as it would be too difficult to pulverize. The calcine or semi-fusion was chilled by plunging while hot into cold water and the friable mass resulting was then pulverized in a ball mill. The pulverized calcine and the clays were then mixed in such proportions as to produce a porcelain having the same chemical composition as the normal porcelain with which it was compared. For this study the following bodies were prepared:

	Body I. Per cent.	Body J. Per cent.	
Canadian feldspar	20	20	Calcined at cone 3.
Whiting	2	2	
Flint	33	33	
Tennessee ball clay No. 7	10	10	
Florida kaolin	10	10	
Edgar Georgia kaolin	25	25	

The calcine vitrified to a dense, opaque mass at cone 3. A microscopic study disclosed, however, that all of the flint had not dissolved but that about 10 to 12 per cent free flint remained. The calcine, after removal from the kiln, was reheated and plunged

into cold water, resulting in the shattering of the mass into small fragments which were ground in about 5 hours into a powder which passed a 200-mesh sieve with 2 per cent residue.

The two bodies, I and J, were made up and fired to cones 7 and 10.

At cone 7, Body I developed a cream color and an absorption of 4.4 per cent, while Body J developed a good white color and had a vitreous structure, the absorption being 2.12 per cent. At cone 10, Body I developed a pale-cream color and an absorption of 0.7 per cent, while Body J was blue-white in color and non-absorbent. The color and absorption were thus greatly improved by the calcination of the non-plastics.

The two bodies were then tested for resistance to sudden temperature changes with the following results: Body J, even though of denser structure, possessed approximately three times the resistance to sudden temperature change displayed by Body I—prepared exclusively from raw materials.

Conclusions.

By calcining or semi-fusing the fluxes and flint prior to incorporation in a porcelain body, the maturing point can be lowered approximately two cones, the color vastly improved, and the resistance to sudden temperature changes improved approximately 200 per cent.

The objection to such a method of manufacture is the extra cost of preparing such a calcine. To offset this we have the saving in kiln maintenance and the fuel saving from the lowering of the maturing temperature of the bisque fire. The degree of pulverization necessary in the feldspar used could doubtless be reduced somewhat which would also mean some saving.

Another possibility which is apparent from this study is the reduction in the amount of flux required in case a lowering of the firing temperature is not desired.

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A SIMPLIFIED APPARATUS FOR THE DETERMINATION OF AIR IN CLAY.

By H. Spurrier.

During the last year the determination of air in pugged clay has assumed increasing importance. It became desirable to simplify the determination so that it might be performed as a factory routine test by entirely unskilled help.

All efforts failed to simplify the previously described apparatus[1] sufficiently to make it a hardy, accurate, and at the same time, safe piece of apparatus to put into factory hands; consequently, it was determined to abandon any corrections, and to simply disengage the gases occluded in the clay by the use of air-free and nearly boiling water, and to see how nearly these results agreed with those obtained by the more elaborate apparatus. Accordingly, a broken burette was cut off evenly and fused to the shortened tail-piece of a large "carbon funnel" which was placed, inverted, in a liter beaker (Fig. 1).

The clay blanks are prepared of such a size that they may easily be placed in the bell of the funnel. 800 cc. of water is placed in the beaker and boiled for some time. The funnel is inserted into the beaker, the stop-cock at the upper end being open. By means of a short piece of rubber tubing fitted to the inverted tip of the burette cock, the water is sucked up till it fills the apparatus to the bore of the cock, thus moving the air entirely from the apparatus. The bell is now raised high enough so that it may be rapidly lowered over the blank which is quickly placed in the vessel of water. The evolution of the air goes on concurrently with the slaking down of the clay blank.

The separation of the air enmeshed in the finely disintegrated clay is greatly facilitated by a rapid gyration of small amplitude,

[1] *J. Am. Ceram. Soc.*, 1, 710–715 (1918).

coupled with a slight up- and down-motion; this may be accomplished without the escape of any air from the apparatus. After a few minutes all of the air is collected in the upper portion of the burette and the reading is taken. The froth that collects

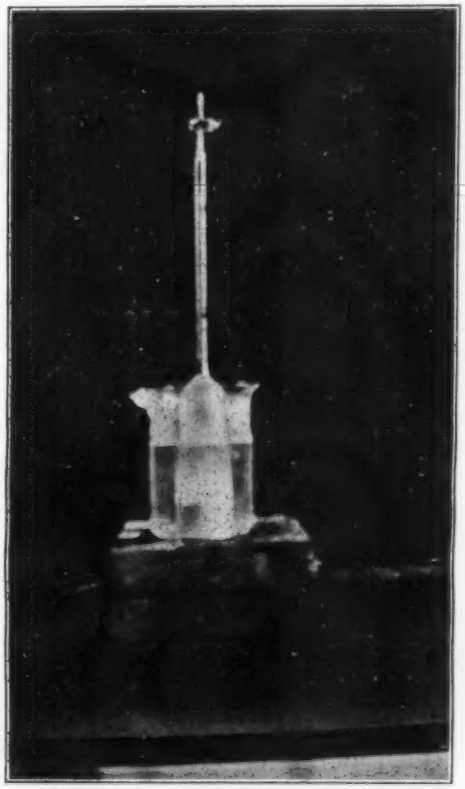

FIG. 1.

above the water line is neglected. The percentage volume of air is calculated on the basis of the volume of the blank used.

Undoubtedly errors are involved in this procedure, but it was foreseen that they would be of a compensatory nature, as proven by the results.

So successful were the results of the tests that a suitably designed one-piece apparatus was ordered from the local glass-blower. The photograph (Fig. 1) shows the apparatus as used and the drawing (Fig. 2) shows the dimensions found suitable for testing our clay blanks.

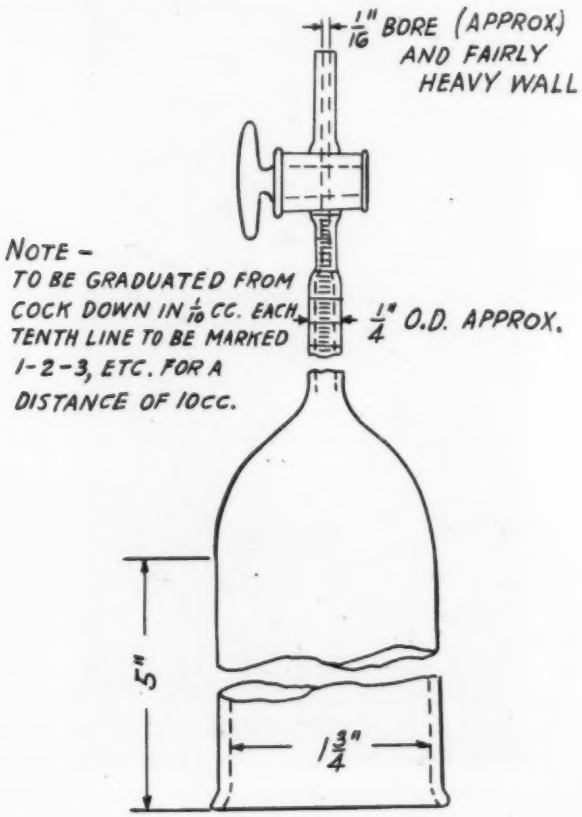
1/16" BORE (APPROX.) AND FAIRLY HEAVY WALL
NOTE - TO BE GRADUATED FROM COCK DOWN IN 1/10 CC. EACH TENTH LINE TO BE MARKED 1-2-3, ETC. FOR A DISTANCE OF 10CC.
1/4" O.D. APPROX.
5"
1 3/4"

FIG. 2.

Routine results have amply justified the expenditure of time involved, as anyone of average intelligence may be instructed in the use of the apparatus in one-half hour and can make a large number of determinations concurrently. For convenience, and

to avoid all calculations, charts were prepared showing the percentage of air by volume calculated on the various sizes of blanks in use, so that the operator reads off the volume of air separated and refers to his table for its percentage—which is duly recorded in the process-inspection report.

JEFFERY-DEWITT COMPANY,
DETROIT, MICHIGAN.

CERAMIC ABSTRACTS.

Abstractors.

E. D. ELSTON — J. S. LAIRD
EARLE N. JESSOP — G. E. MIDDLETON
CHAS. H. KERR — H. G. SCHURECHT
F. A. KIRKPATRICK — CHESTER TREISCHEL

Microscopic examination of clays. R. E. SOMERS. *J. Wash. Acad. Sci.*, **9**, 113–126, (1919).—The investigations as stated by Somers are not intended to be exhaustive. Nevertheless the results are well worth some attention. The microscopic examination was made to determine the mineral content and in some cases petrographic study was made of the burned samples in order to ascertain, if possible, what changes occurred during the burning. By means of a table the author has contrived to place before the reader in a more graphic form the mineral content of the unburned clays together with a comparative measure of the relative abundance of the more important minerals in each sample. Such a method is greatly benefited by the author's brief description regarding the identification of the various minerals.

Of special interest is the fact that Somers states that hydromica is apparently quite abundant in some of the clays examined. Further, "the hydromica has single and double refractions higher than those of kaolinite, yet not so high as muscovite or sericite" and that "the degree of these refractions varies in different clays." Therefore, Somers assumes "that there is an isomorphous gradation between sericite and kaolinite, with a gradual loss of potash and addition of water, and, in weathering products such as these, hydromica represents a transition stage of weathering toward kaolinite as a final product." In addition to abundance of hydromica in some clays as shown by petrographic examination, Somers thinks that since many kaolins show by chemical analysis a small percentage of potash, the latter may be regarded as belonging to the mica, inasmuch as feldspar seems to be very scarce. Halloysite was found in but two of the many clays examined while rutile in some amount was contained in practically all of them. Thin sections disclosed the presence in some of the clays of tourmaline, epidote, zircon, titanite and diaspore.

Some of the clays were burned and thin sections of the fired material were examined with the results that the following facts were noted: Quartz grains were more prominent in the fired product than in the raw clay—due to the fusing of the hydrous aluminum silicates into a fine-grained mass holding the quartz. In some specimens a fluxing action appeared to have occurred between the fine-grained material and the silica, with resulting corrosion of the quartz. This, according to the author, was comparatively rare. Since

the hydromica, on heating to 1150° C, either disappears or loses most of its interference colors, it would seem that it may furnish some of the flux for the clay. Tourmaline and probably epidote disappear at 1150° C, but rutile zircon and probably titanite apparently are persistent at 1300° C.

It is interesting to note that in a Florida white clay fired at 1300° C sillimanite developed from the large flakes of kaolinite or low-grade hydromica as indicated by one flake containing both minerals. The actual cause for its development, however, is unknown. Other clays containing similar micaceous particles did not show sillimanite when burned, although they were fired at the same time as the Florida sample. In Mr. Somer's opinion this development of sillimanite by burning and its presence in porcelain may explain the cause of double refraction produced in the ground mass of some clays by burning to higher temperatures. The tables given in the article also show the texture of clay, the relative abundance of the important constituents, and the porosity after burning. E. D. ELSTON.

Baked shale and slag formed by the burning of coal beds. G. SHERBURNE ROGERS. U. S. Geol. Surv., *Prof. Paper* **108-A,** (1917).—The effects produced by the burning of coal beds have been observed particularly in portions of Montana. Mr. Rogers is of the opinion that ignition, which in some instances may be due to any one of a series of causes, such as lightning, forest or prairie fires, or to the agency of man, appears in most cases to be due to spontaneous combustion. The appearance of the rocks overlying a burned coal bed varies, ranging from reddened and only slightly hardened condition of the shales or sandstone through glassy slag to gray medium-grained rock. These differences seem to be due chiefly to the degree of heat to which the material has been subjected. The combustion, according to Mr. Rogers, apparently starts at the surface, spreading first along the outcrop. As the coal burns out the overburden generally caves, and large fissures may result. During this stage of the burning the overlying strata are not greatly affected, owing to the dissipation of the heat. Clay partings, however, may be baked to form thin, red bands. With the progressive burning back from the outcrop the overlying rocks are more strongly affected. The underlying rocks are only slightly changed, if at all. From the burning beds upward there appears to be a gradual transition. Near the burning bed and extending upward a few feet the rocks may be partly fused. Above they are in general only baked and further up only slightly reddened. Much of the shale is hardened or vitrified, although the sandy material may be only slightly affected. The reddening of the rock, according to Rogers, is due to moderate heat and implies no extensive chemical change.

In general, the shale or sandstone in more or less baked condition forms the larger part of the metamorphosed materials. The shales lost their original texture, becoming hard and massive. Conchoidal or splintery fracture is not uncommon and many specimens resemble jasper. Commonly the rock is mottled, probably due to higher temperature and the colors produced by irregular oxidation of iron. The vitrified portions display in thin sections

the presence of hematite and magnetite, the former in the red areas while the latter occurs in green and black areas. The rock is rough and vesicular, somewhat similar to some types of brick. Notable among the chemical changes, is dehydration under conditions favorable to oxidation. This affects chiefly the ferrous iron compounds, which are converted to hematite with reddening of the rock. E. D. ELSTON.

"Clay-working industries and building operations in the larger cities in 1917." JEFFERSON MIDDLETON. U. S. Geol. Surv., *Min. Res. of U. S.*, Part II, 28(1917).—For general conditions of the clay industries, including tables showing production, this publication, though not dealing with specific location and detailed accounts, presents much material commercially interesting to clay workers. E. D. ELSTON.

Electricity in the ceramic arts. J. P. ALEXANDER. *Gen. Elec. Rev.*, **22,** No. 2 (Feb., 1919).—"Until recent years, electricity had not been introduced into pottery and tile-making factories for the reason that it had been generally supposed that a steam engine, by reason of the excess power it could produce over its normal rating, was the only driver that could start up the machinery after the clay had settled in the mixing tubs overnight. Recent electrical installations have shown the fallacy of this idea, and have proved to ceramic engineers that the electric motor can duplicate any of the engine drives." The writer proceeds to detailed descriptions of the various processes employed by the ceramic industry and outlines the increasing service afforded by electricity in this field. C. TREISCHEL.

Crystalloids against colloids in the theory of cements. H. LE CHATELIER. *Trans. Faraday Soc.*, **14,** 8 (1919).—The colloidal theory of the hardening of cements is devoid of sense. In a similar way it used to be said that bodies react because they have affinity for each other. The explanation seems to come down to this: cements harden because they have the property of hardening. Let us define the word "colloid" if possible. Graham found a certain few distinctions between "colloids" and "crystalloids." Zsigmondy showed that the collidal solutions were merely suspensions of very finely divided, rigorously insoluble matter. All very minute insoluble bodies give such colloidal suspensions. But is there cause to give a particular name to bodies, the only singular properties of which so far are insolubility and fineness? These very minute bodies possess, however, one quite special and very important property, which entitles them to be classed separately, that is the property of absorbing the soluble bodies which are held in solution by the liquid with which they are wetted. This property manifests itself also in porous bodies, such as blood carbon and wood charcoal. Hence, from this point of view, colloids and porous bodies must be classed together. This absorptive power is a particular case of much more general properties which all very fine bodies possess. These particular properties are under the sway of surface tension. All chemistry is only a chapter on energy; but there is one form of energy of which chemistry does not speak as a rule, that is

surface energy, which is measured by the product of the surface tension and of the free surface of the body. The surface energy of water, for example, in the form of a sphere weighing 18 gm. is 6.3×10^{-8} kg. calories. If this sphere were divided into globules, each 10^{-6} mm. in diameter, the surface energy would be equivalent to 2 calories, or of the order of magnitude of the quantity of heat which water evolves in its various chemical reactions. Certain indirect considerations lead us to admit that surface tension of solids in suspension may become a hundred times greater than that of water. However, we have not yet considered the solubility of the bodies in question. A solid crystal ground to very fine grains will have all the properties of colloids until it is brought into contact with a liquid which can partially dissolve it. There will result an increase in the solubility of the fine crystals and large crystals will soon separate out. This has been verified for the very fine ppts. of CaC_2O_4 and $BaSO_4$. We come now to hydraulic mortars. When plaster of paris has set, we can never discern any crystals in the material, even under the strongest magnification of the microscope. That does not prove that no crystals are formed; perhaps they are too small to be recognized. They do form in several weeks if the plaster is left to itself or if the plaster is gauged with alcoholic water. The calcium aluminates, which play an important part in the hardening of rapidly setting cements, are hydrated at the same rate as the plaster of paris, and they give likewise a whitish mass in which crystals are not discernible. If instead of gauging the aluminate with a deficiency of water we put a few isolated grains into a large volume of water, we observe that the grains soon become surrounded by long crystals of hydrated aluminate, which are always easily visible under the microscope and can sometimes be seen directly by the eye. The microscope has never enabled us to see hydrated calcium silicate ($CaOSiO_2 \times H_2O$). Its crystals are certainly very minute. Numerous analogies prevent us, however, from denying their existence. Crystals of barium silicate can always be seen with the aid of a lens, sometimes even with the naked eye. Hence, we may say by analogy that calcium silicate crystals will form, although they are, on account of their smaller solubility, too minute to be discernible. It is not impossible that, initially, the dimensions of these crystals are of colloidal order. In the course of time the dimensions of the crystals must increase considerably, as in all similar instances. The mechanical resistance does not diminish with time, quite to the contrary. Consequently, the colloidal state which was possible at the beginning has nothing to do with the hardening of the cement. The anhydrous compounds of cements, not being in chemical equilibrium when in contact with water, are more soluble than the same hydrated compounds. For this reason they give rise to the formation of a supersatd. solution from which the dehydrated compound may rapidly crystallize. The liquid, being no longer saturated, can redissolve more of the anhydrous compounds and the whole mass can thus crystallize progressively by passing through a stage of transitory dissolution in a limited volume of water, which, at any given moment, cannot maintain in solution more than a small portion of the total mass of salts present. The crystals which are deposited from the

supersaturated solutions always appear in the shape of extremely elongated needles, which have the tendency to group themselves in spherulites about the centers of crystallization. The entanglement of all these crystals is the only cause of the solidity of mass; they adhere by simple contact, as do all solid bodies when resting upon one another. Friction at the points of contact, even in the absence of all adhesion, suffices to produce great mechanical resistance, such as is found in all tissues and fabrics whose solidity has no other origin. Adhesion is increased and friction decreased by the growth of the crystals. A material built up of very wide strips could be very solid if the strips were glued together at their contact surface.

F. A. KIRKPATRICK.

ethods of fuel conservation in cement mill operations. ERNEST ASHTON. *Concrete Cement Mill Section,* **13,** 45 (1918).—(1) The fusion temperature of the cement may often be lowered by addition of the proper ingredients. (2) Uniformity of size of particle is more desirable than extreme fineness of part of the material. The fine material fuses sooner than the coarse, causing the formation of balls which do not burn properly. (3) The rate of feeding and the speed of the kiln should be so regulated that the amount of raw material will be the maximum that can be carried without cooling the kiln when the greatest amount of coal that can be burned with complete combustion is being blown into the kiln. (4) The Bureau of Mines' recommendations in regard to storage of coal should be carried out as closely as possible. (5) The coal should be ground uniformly and finely. (6) Utilization of stack and clinker heat should be more thoroughly studied and the necessary installation of equipment made. The kiln of the future should be almost air-sealed at the front, with preheated air to aid combustion, and waste heat boilers should be used. (7) There are described economical methods of oil burning for cement kilns. (8) Power plant operation should be as thoroughly controlled as it is in any modern industrial plant.

F. A. KIRKPATRICK.

Furnaces for obtaining high temperatures. A. BIGOT. *Chemie et Industrie,* **2,** 27–36 (1919).—A laboratory furnace in which specimens of considerable size can be heated to 1750° C has been developed by modifying the design of the Perrot down-draft pot furnace. The iron pipes used in the latter for carrying off the products of combustion and for introducing the secondary air in such a way that part of the heat of the waste gases is recuperated have been replaced by a refractory tube carried in a well insulated refractory flue, so that the air is highly preheated. The furnace proper is lined with fused alumina and is very carefully insulated. With a capacity of about 2 cu. ft. it requires about 300 cu. ft. of gas per hour to heat it to 1750° C in 6 hours. The author has also developed industrial continuous kilns in which he obtains great economy by making use of the same principles of insulation and recuperation. In these the cars with iron wheels used in other tunnel kilns have been replaced by conveyors made of refractory slabs which

roll on refractory balls set in the refractory slabs which line the bottom of the kiln. These refractories, made of special composition not given in the article, have at 1100° C a crushing strength of about 20,000 pounds per sq. in. For kiln temperatures above 1100° C, at which the refractories would become much weaker, the movable parts are sunk in a trench to protect them from overheating. The mass of material to be heated is much less than it is when ordinary cars are used. Firing, preheating and cooling are carried on as in other types of tunnel kilns. Kilns are 100–150 ft. long, and have an output of 15–25 tons of clay-ware per day. The kilns are being used for the firing of various kinds of ware, including silica and other refractories. The maximum length of firing is 5 days. The following comparative data are given:

	Percent of heat utilized at		
Type of kiln.	1000° C.	1250° C.	1400° C.
Intermittent	20%	....	10%
Hofmann	40%	40%	....
Car tunnel kiln	80%	50%	40%
Bigot tunnel kiln	....	78%	70%

Ware.	Temp of firing.	Fuel consumption per ton product.
Stoneware	1250° C	100 lbs.
Porcelain	1350° C	122 lbs.
Bauxite, chrome	1450° C	150 lbs.
Magnesia	1530° C	210 lbs.
Silica	1530° C (longer fire)	260 lbs.

J. S. LAIRD.

CERAMIC PATENTS.

G. E. MIDDLETON, *Abstractor.*

Brick or tile dies. C. H. BRISBIN. U. S. 1,301,095, Apr. 22, 1919.—The lower die of the set consists of two plates normally spaced apart by spiral springs. There are cores on the lower plate projecting through apertures on the upper, the ends of the cores being held normally flush with the upper surface. Under compression the plates contact and the cores project above the surface of the upper plate, forming depressions in the brick or tile. When the pressure is removed, the cores recede and the brick or tile may be slid from the die surface.

Apparatus for manufacturing hollow glassware. L. N. BRUNER. U. S. 1,301,378, Apr. 22, 1919. A machine for molding short, glass tubes or cylinders. The article is formed by centrifugal force in a rotating mold provided with a cup which works up and down therein pistonwise. The cup is raised to the top of the mold to receive the glass and is then lowered to the bottom thereof, the mold being rapidly rotated, thus causing the glass to spread evenly up the inside of the mold.

Apparatus for making bricks. H. W. B. GRAHAM. U. S. 1,301,685, Apr. 22, 1919. A soft mud brick machine in which the molds are filled, dumped, sanded and returned and the brick carried off, mechanically.

Method of and apparatus for forming glass tubes. K. KUEPPERS. U. S. 1,301,714, Apr. 22, 1919. Glass tubes of exact inner form are made by mounting the tubes on a mandrel of the desired shape, heating to soften, and pressing the tubes around the mandrel in successive stages lengthwise thereof.

Method of drawing hollow glass articles. O. A. WELLS. U. S. 1,301,771, April 22, 1919. Hollow glass articles are drawn by a process involving the use of a heated bait having a temperature below that at which glass will fuse thereto, but high enough to have substantially the same radial contraction during the draw as that which occurs in the novel of the glass article being drawn.

Brick for brick presses. C. W. WILKINSON. U. S. 1,302,113, Apr. 29, 1919. A brake band extends about the periphery of the rotary table of a brick press, its function being automatically to stop the rotary table and hold it after each movement and during the pressing operation, thus preventing the so-called back lashing or rearward movement of the table.

Drawing-pot for glass. R. L. AND F. J. FRINK. U. S. 1,302,149, April 29, 1919. An apparatus designed for melting and distributing or draining off the solidified glass which accumulates in drawing pots to which the metal is periodically introduced by dipping. Two pots are mounted, one at either end of a horizontally rotatable frame, and while a cylinder is being drawn from one, the other, tilted to a vertical position, is being subjected to an ignited gas blast which melts the accumulated glass and allows it to drain off. There are also means for introducing air at the base of the rising cylinder and through the bottom of the drawing-pot.

Press for lavatories. D. W. MCNEIL. U. S. 1,302,191, April 29, 1919. A fluid-operated dry-press designed to mold lavatories of the type having an integrally formed back or splash board, a rolled rim, an integrally formed apron, and a hidden overflow passage.

Structural composition. E. R. TAYLOR AND I. FLEXNER. U. S. 1,302,452, Apr. 29, 1919. A composition adapted for use in constructing buildings and for similar purposes. It is said to be dense, compact, soundproof, of substantial transverse strength and of a specific gravity about one-half that of ordinary concrete. Nails can be readily driven into it. The composition is variable within limits, an example being Portland cement 96 parts, mineral fiber, such as asbestos 24 parts, sawdust 6 parts, sand 8 parts.

DIVISIONS AND SECTIONS

Refractories Division.

A meeting of the Refractories Division of the American Ceramic Society will be held at Niagara Falls, August 4th, in connection with the Summer meeting of the Society. It is very important that as full an attendance as possible be had, owing to the fact that several important matters dealing with the future work of the Division will be discussed.

(Signed) A. V. BLEININGER,
Chairman.

Northern Ohio Section.

A meeting of the Northern Ohio Section of the American Ceramic Society was held at "Willoughbeach," Cleveland, O., on Monday, June 23, 1919.

After luncheon at the Hotel Cleveland, the party proceeded by trolley to "Willoughbeach." A business session was first held at which matters pertaining to the constitution of the Section and the arrangements for the Summer meeting of the American Ceramic Society, in Buffalo and Cleveland the first week in August, were discussed.

At the request of certain members of the Section, instead of the usual series of formal papers, the meeting was devoted mainly to a "Symposium on Fuels," particularly substitutes for natural gas. This included a discussion of the relative merits of coal, powdered coal, producer-gas, oil, etc. As a part of the discussion, Mr. W. T. Dean, President, General Combustion Co., presented an interesting paper on "Fuel Oil and Methods of Burning Same."

Following the meeting the members enjoyed the bathing and other facilities for amusement at the beach.

B. A. RICE, *Secretary.*

Eastern Section.

The Summer meeting of the New Jersey Clay Workers' Association and Eastern Section of the American Ceramic Society

was held at the Trenton Country Club, Trenton, N. J., on Tuesday, June 24, 1919.

At the opening session in the morning the charter granted by the American Ceramic Society to the Eastern Section was accepted and the following officers were elected to serve for the balance of the year:

Councilor, Charles A. Bloomfield, Metuchen, N. J.

Chairman, Charles H. Cook, Cook Pottery Co., Trenton, N. J.

Vice-Chairman, Abel Hansen, Fords Porcelain Wks., Perth Amboy, N. J.

Secretary-Treasurer, George H. Brown, Rutgers College, New Brunswick, N. J.

The following program was then presented:

Address by the Chairman, Charles H. Cook.

"Methods of Ceramic Kiln Control," G. H. Brown, New Brunswick, N. J.

"Some Data on the Development of Terra Cotta Glazes," by E. C. Hill, Conkling-Armstrong Terra Cotta Co., Philadelphia, Pa.

"A Plea for the Use of Precise Data in Ceramics," by A. V. Bleininger, Bureau of Standards, Pittsburgh, Pa.

"Ceramic Kiln Insulation," by P. A. Boeck, Celite Products Co., New York, N. Y.

"Some Aspects of Ball Mill Grinding," by Leslie Brown, Lenox, Inc., Trenton, N. J.

Luncheon was served at the Country Club during the intermission between the morning and afternoon sessions. A feature of the meeting was the discussion of the foundation of a ceramic museum in which will be displayed specimens of ceramic products of all kinds manufactured in the State of New Jersey. The nucleus of the exhibit was on display at the meeting and included a specimen of the first pottery manufactured in New Jersey. The meeting was a very satisfactory one in every respect. More than 90 were in attendance.

Adjourned.

G. H. BROWN, *Secretary-Treasurer.*

ANNOUNCEMENT

1919 Summer Meeting.

AMERICAN CERAMIC SOCIETY.

Buffalo, Monday, August 4, 1919.

Members will convene in Buffalo on Monday morning, August 4th. Points of interest in and around Buffalo and Niagara Falls will be visited and the party will proceed by boat on Wednesday to Cleveland. The Buffalo local committee is endeavoring to arrange such interesting trips for the ladies as an inspection of the factory of the Larkin Company and the Shredded Wheat plant, and they will also enjoy the Falls and the ride on Lake Erie. The Iroquois Hotel has been selected as headquarters at Buffalo.

Cleveland, Thursday, August 7, 1919.

Members will arrive on the Buffalo boat at eight o'clock and will breakfast at the new Cleveland Hotel. Choice will then be given for several trips:

1. Enameled Products Company.
2. Vitreous Enameling Company.
3. Cleveland Metal Products Company.
4. Nela Park, Research "University" of the National Electric Lamp Co.
5. National Carbon Company.

There may also be an opportunity to visit the Bedford China Company, Bedford, Ohio.

The party will lunch at the Hotel Cleveland and afterwards go to the Cleveland Yacht Club where a complimentary smoker and dinner will be given by the Northern Ohio Section of the American Ceramic Society.

This post-war meeting promises to be one of the best summer meetings ever held by the Society. Members should arrange vacations so that they can combine the enjoyment of the scenic

beauties of Niagara Falls and a boat trip on Lake Erie with the social and educational features which characterize the meetings of the A. C. S.

S. C. LINBARGER,
Chairman, Buffalo Local Committee.
R. D. LANDRUM,
Chairman, Cleveland Local Committee.

Acquisition of New Members during June, 1919.

Associate.

Behrent, Leo A., Midland Terra Cotta Co., Chicago, Ill.
Blank, Wm. C., Ills. Pacific Glass Co., San Francisco, California.
Davies, J L., Clayton, Wash.
Finney, Robert S., Hotel Cumberland, New York City.
Hathaway, C. W., National Enameling and Stamping Co., Granite City, Ill.
Slater, W. M., 522 F St., N. W., Washington, D. C.
Swinnerton, B. B., 148 Taylor Ave., Beaver, Pa.
Wethey, Jr., A. H., Standard Brick & Tile Co., Portland, Oregon.

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¶ Actual records were kept for 365 days of the burning of 9-inch, high-grade, refractory brick in one continuous tunnel kiln and in seven 30-foot round kilns, during which time 5,110,000 brick were burned in the tunnel kiln as against 5,040,000 in the seven round kilns.

¶ But this isn't all—the actual labor saving amounted to $5,808.00. Taking into consideration the necessary items of depreciation, interest on plant, maintenance and repairs, the average yearly cost for burning 1,000 brick in the continuous tunnel kiln system was $2.95 as against $6.20 in the round kilns.

¶ If you are really interested in the greater efficiency of burning, you will let us tell you more about the actual accomplishments of

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Edgar Georgia Paper Clay and Kaolin	*Edgar Brothers Co.*
Lake County Florida Clay	*Lake County Clay Co.*

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Second:—This twin tunnel kiln allows a greater utilization of the fuel than a single tunnel kiln, as the heat from cooling ware is used for water-smoking the incoming ware.

Third:—This kiln allows an absolute and positive control of the firing zone, and in the firing zone a reducing or oxidizing condition can be maintained at will.

Fourth:—The cooling of the ware as well as the water-smoking and pre-heating in this kiln are absolutely automatic. It is impossible to get the receiving end of the tunnel too hot.

Fifth:—This kiln will save about 50% on labor and from 65% to 75% on fuel as compared with periodic kilns. Burning time is cut down by ⅓ to ½. Where saggers are used, they will last twice as long.

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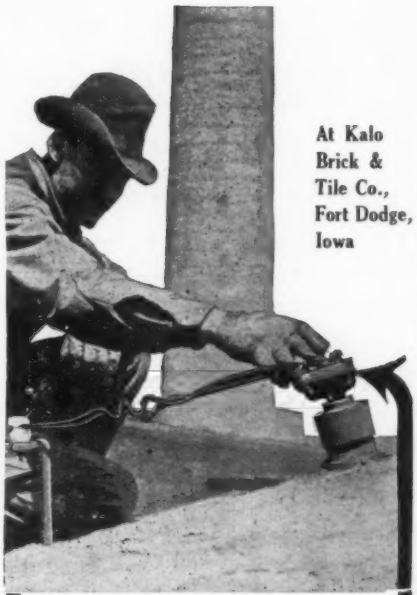

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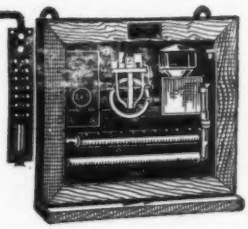

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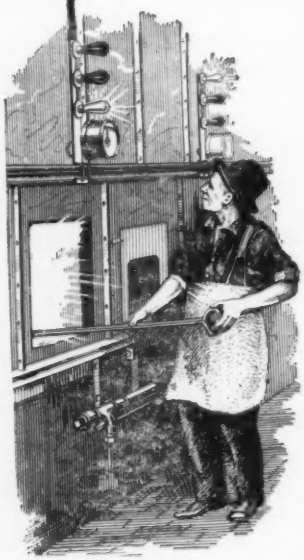

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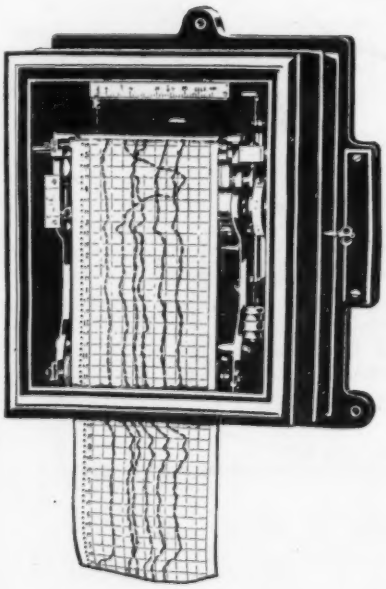

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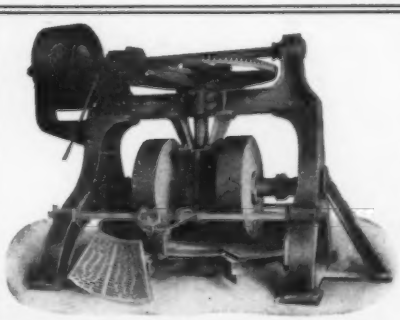

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